MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

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Maryland Tributary Strategy Patuxent River Basin Summary Report for 1985-2004 Data

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Maryland Tributary Strategy Patuxent River Basin Summary Report for 1985-2004 Data

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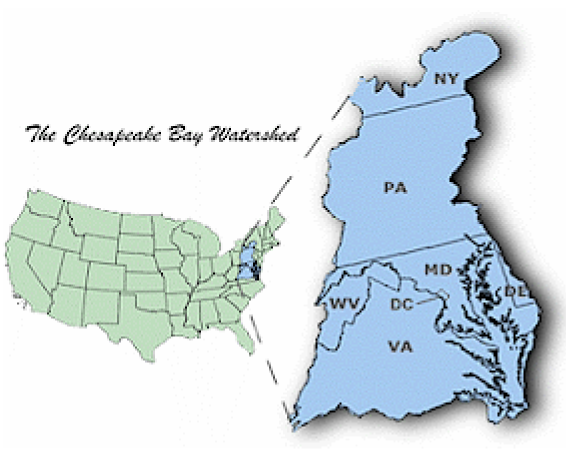
Introduction

The Chesapeake Bay is the largest estuary in North America. A national treasure, the Bay is famous for providing delicious seafood as well as a myriad of recreational and livelihood opportunities, such as boating, fishing, crabbing, swimming, and bird-watching.

By the 1970s, however, our treasured Bay was in serious decline. In 1975, the United States Congress directed the Environmental Protection Agency (USEPA) to conduct a comprehensive study of the most important problems affecting the Chesapeake Bay. The findings of this study formed the crux of the first Chesapeake Bay Agreement, signed in 1983 by Maryland, Virginia, Pennsylvania, Washington DC, the Chesapeake Bay Commission and the USEPA. Additional scientific information gained from monitoring data and modeling efforts was used to amend that Agreement, resulting in the 2000 Chesapeake Bay Agreement (http://www.chesapeakebay.net/agreement.htm).

Science showed that three of the biggest problems facing the health of the Chesapeake Bay and its tributaries (the rivers and streams that flow into the Bay) are excess nitrogen, phosphorus, and sediments. The nutrients nitrogen and phosphorus fuel excessive algae growth. These algae, as well as suspended sediments, cloud the water and prevent Bay grasses from getting enough light; Bay grasses provide essential habitat for crabs and fish as well as food for waterfowl. When algae blooms die, they decompose using up essential oxygen. This lack of oxygen kills bottom-dwellers such as clams and sometimes fish. Another problem with excess nutrients is that they sometimes favor the growth of harmful algae. Harmful algae can be toxic to aquatic animals and even humans. For more details on the Bay's ecosystem and the problems facing it, see http://www.dnr.state.md.us/Bay/monitoring/mon_mngmt_actions/monitoring_mgmt_actions.html.

Figure PXT1



The health and vitality of the Chesapeake Bay is a product of what happens in the watershed, the land area the drains into it. The Chesapeake Bay watershed covers 64,000 square miles, and includes land in six states plus Washington DC (Figure PXT1).

To help achieve Maryland's share of the reductions in nitrogen, phosphorus, and sediment to the Bay and its tributaries a Tributary Strategy Team has been appointed for each of the ten Chesapeake Bay subwatersheds in Maryland:

- Upper Western Shore Basin
- Patapsco/Back Rivers Basin
- Lower Western Shore Basin

- Patuxent River Basin
- Upper Potomac River Basin
- Middle Potomac River Basin
- Lower Potomac River Basin
- Upper Eastern Shore Basin
- Choptank Basin
- Lower Eastern Shore Basin

Each team is comprised of business leaders, farmers, citizens, and state and local government representatives who work together to identify the best ways to reduce nutrient and sediment inputs to the Bay.

This report provides:

- Patuxent River basin characteristics
- Nutrient and sediment loadings to the Patuxent River based on model results (the model is developed using monitoring data)
- Overview of monitoring results
    - links to indepth non-tidal water quality information
    - tidal and non-tidal water quality status and trends (based on monitoring data, i.e., measured concentrations from 1985 to 2003)
    - Bay grasses acreage over time
    - long-term information on benthic (bottom-dwelling) community health
    - information on phytoplankton
    - information on zooplankton
    - nutrient limitation information
- individual wastewater treatment plant outputs

The goal of this report is to show current status of the habitat and water quality (how good or bad it is) and long-term trends (how has water quality and habitat improved or worsened since 1985) provided within the context of information about the basin.

Patuxent River Basin Characteristics

The Patuxent River is the largest river completely in Maryland. Its basin drains 932 square miles of land within Maryland's Western Shore (Figure PXT2). This area includes portions of St. Mary's, Calvert, Charles, Anne Arundel, Prince George's, Howard, and Montgomery Counties. Three main streams drain into the upper Patuxent River: the Little Patuxent, which drains much of

the newly urbanized area of Columbia; the Middle Patuxent, which drains agricultural lands in the northern part of its drainage and the outer suburban areas of Columbia in the southern part of its basin; and the (upper) Patuxent River, which has remained primarily agricultural. The Patuxent River basin lies both in the Piedmont and Coastal Plain physiographic provinces.

The Patuxent basin lies between two large metropolitan areas–Baltimore, Maryland and Washington, D.C. Consequently, the watershed has gone through significant suburban development in the past few decades. The 2000 census population for the basin was 618,000 people. The thriving suburban communities of Columbia and Laurel have developed along the Interstate 95 corridor, which bisects the upper half of the basin. The town of Bowie has also undergone much recent development.

The Maryland Department of Planning land use categories are defined as follows:

- urban – includes residential, industrial, institutional (such as schools and churches), mining, and open urban lands (such as golf courses and cemeteries)
- agriculture – includes field, forage, and row and garden croplands; pasturelands; orchards and vineyards; feeding operations; and agricultural building/breeding and training facilities, storage facilities, and built-up farmstead areas
- forest – includes deciduous forest, evergreen forest, mixed forest, and brush
- water – includes rivers, waterways, reservoirs, ponds, and the Bay
- wetlands – includes marshes, swamps, bogs, tidal flats, and wet areas
- barren – includes beaches, bare exposed rock and bare ground

Land use in the basin is 44 percent forest, 30 percent urban, and 26 percent agriculture. The land above the fall line is more urbanized than that below the fall line.

Over 80 percent of the housing in the basin is urban, with most of the remaining housing in rural areas. Concurrent with this large amount of urban housing is a heavy reliance on municipal water and sewage systems. In addition, 77 percent of the basin's housing relies on municipal sewage system and 81 percent of the housing uses a public water source. Contributions from point sources make up roughly one third of the nutrient loadings to the Patuxent River. There are more than 20 sewage plants in the basin (Figure PXT3). Tributary strategy goals for BMPs associated with urbanization have been established to reduce non point source loads from urbanized lands. Good progress has been made toward these.

About a quarter (26 percent) of the Patuxent River basin is agricultural land. A series of Best Management Practices (BMPs) have been planned to help reduce non point source nutrient and sediment loads from agricultural lands. BMP implementation for conservation tillage and sediment control plans are making good progress toward Tributary Strategy goals. As of 1998, progress had been slower for other issues, such as animal waste management, cover crops, grass buffers, nutrient management plans, runoff control, and stream protection.

Figure PXT2 – 2000 Land Use in the Patuxent River Basin

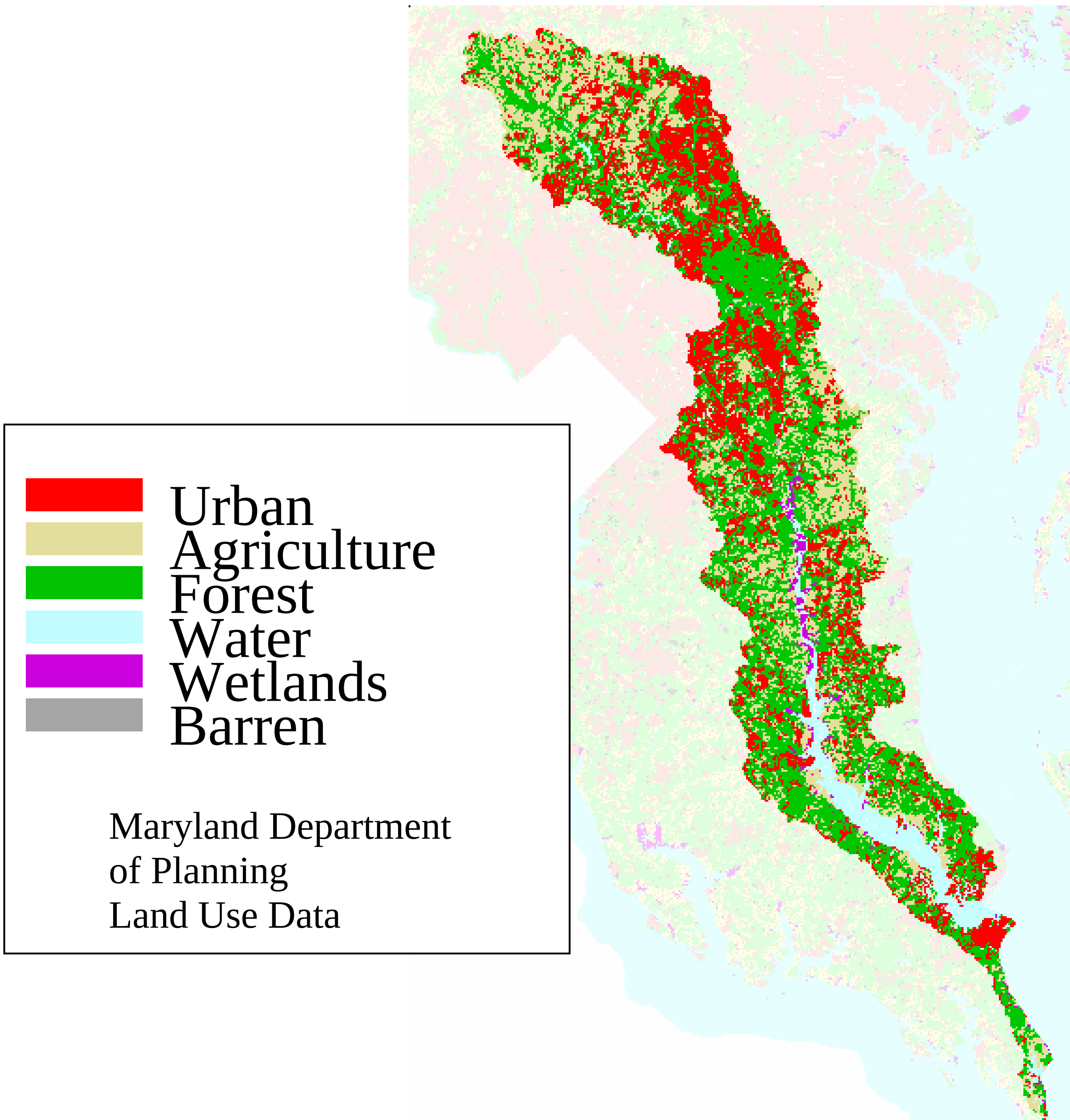
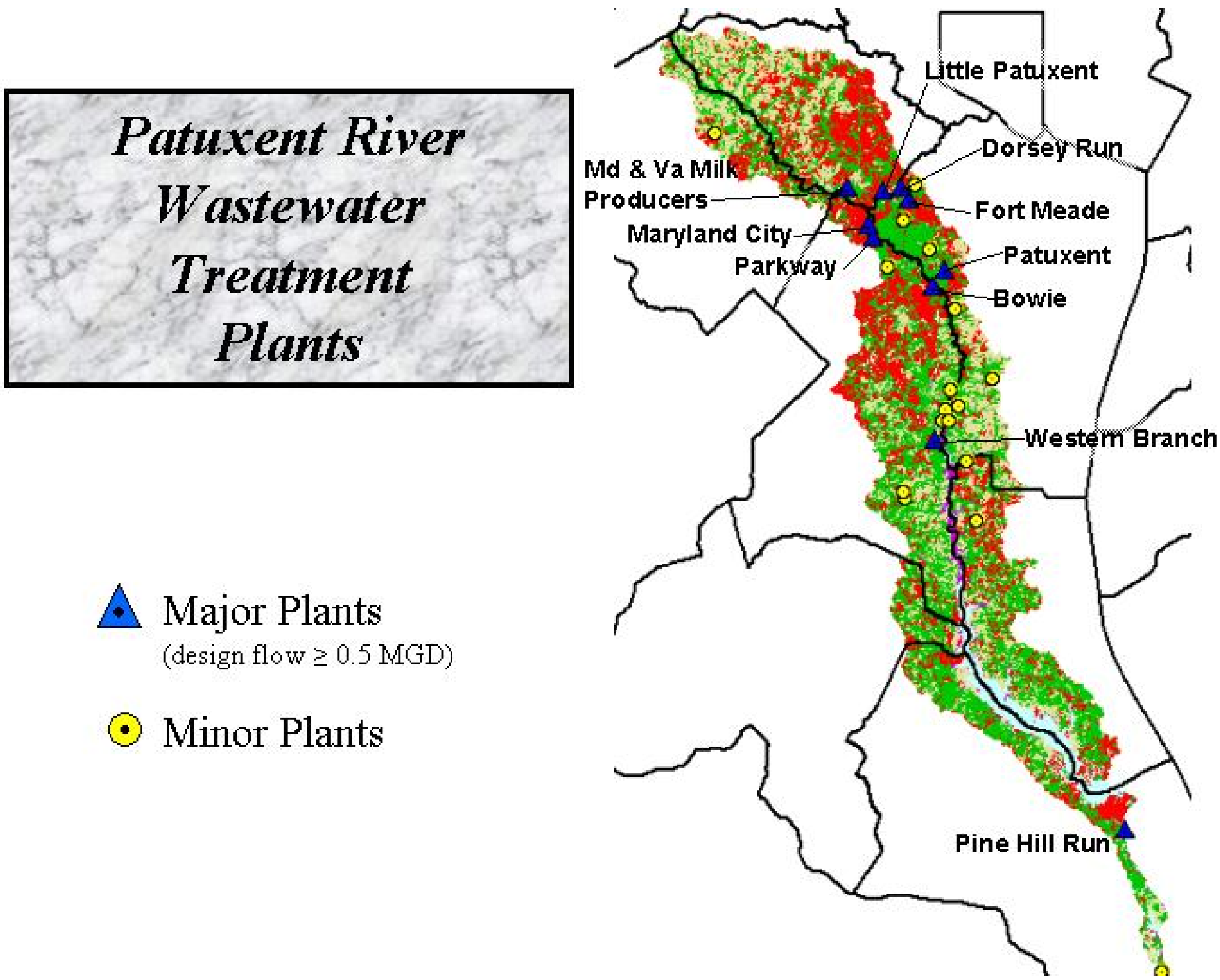


Figure PXT3 – Wastewater Treatment Plants in the Patuxent River Basin



goals with respect to marine pumpouts, shore erosion, septic connections, and stormwater management conversions and retrofits. As of 1998, progress had not been good with respect to enhanced stormwater management, erosion and sediment control, septic pumping, and urban nutrient management.

Almost half of the basin was forested as of 1994 (46 percent). Of BMPs related to forests, forest harvest practices and tree planting have not yet been widely implemented.

The Chesapeake Bay Program model categorizes nutrient and sediment loads from both point sources (end of pipe inputs from wastewater treatment plants and industrial outfalls) and non-point sources. The non-point loads are estimated from a variety of sources including land cover, agriculture records, etc. Generally, the categories in Figures PXT4-PXT6 include:

- point sources – out of pipe from waste water treatment plants and industrial releases
- non-point sources
    - urban – from industrial, residential, institutional, mining and open urban lands
    - agriculture –from row crop, hay, pasture, manure acres
    - forest –from forested lands
    - mixed open –from non-agricultural grasslands including right-of-ways and some golf courses
    - atmospheric deposition to water – deposited from the atmosphere directly to water

For more detailed information, see the document *Chesapeake Bay Watershed Model Land Use Model Linkages to the Airshed and Watershed Models* at **http://www.chesapeakebay.net/pubs/1127.pdf.**

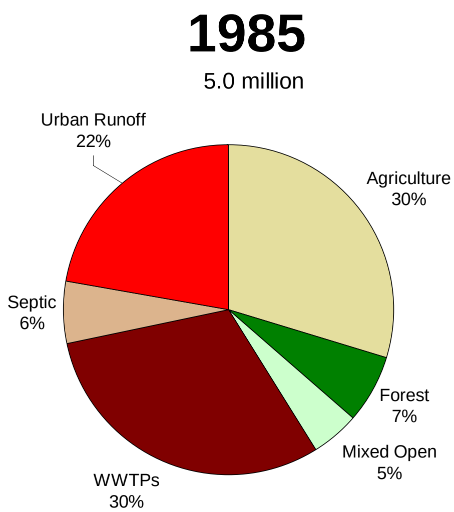
As of 2002, the most significant contributor of nitrogen in the Patuxent River basin were point sources (34 percent) (Figure PXT4). Following that were urban sources (32 percent) and agriculture (21 percent). For phosphorus, the largest contributor was urban sources (36 percent), followed by point sources (30 percent) and agriculture (22 percent) (Figure PXT5). Agriculture was the dominant source of total suspended solids (55 percent) followed by urban sources (28 percent) (Figure PXT6).

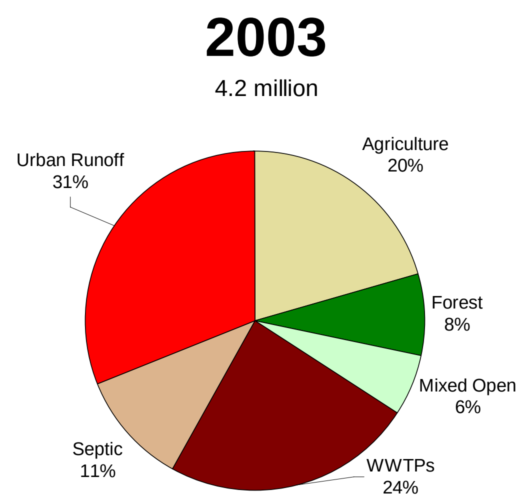
Anne Arundel County has developed a watershed management tool, which reveals the nutrient loading implications of prospective planning decisions in the watershed. Information is available on the Internet at:
http://www.aacounty.org/LandUse/OECR/WatershedManage.cfm.

The watershed supports more than 100 species of fish in its freshwater streams and brackish waters, including largemouth bass, chain pickerel, catfish, weakfish and bluefish. The Patuxent also supports an important commercial and recreational blue crab fishery.

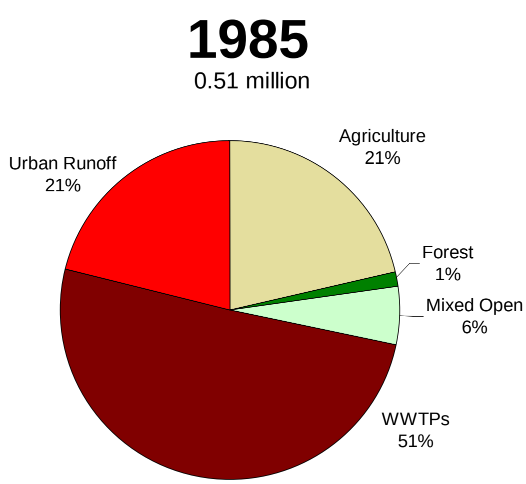
Figures PXT4-PXT6 – 1985 and 2003 Nitrogen, Phosphorus and Sediment Contribution to the Patuxent River by Source.

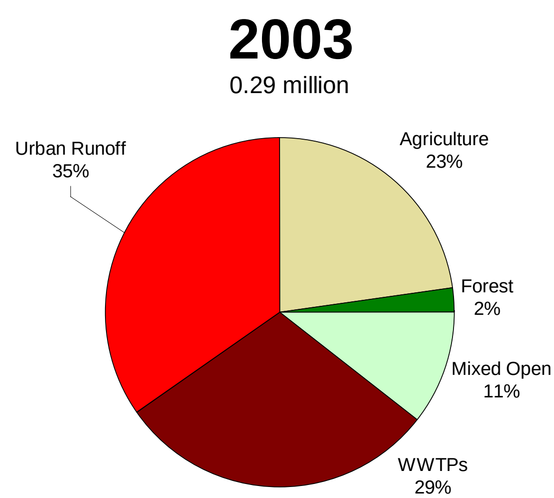
Nitrogen Contribution to Patuxent River by Source



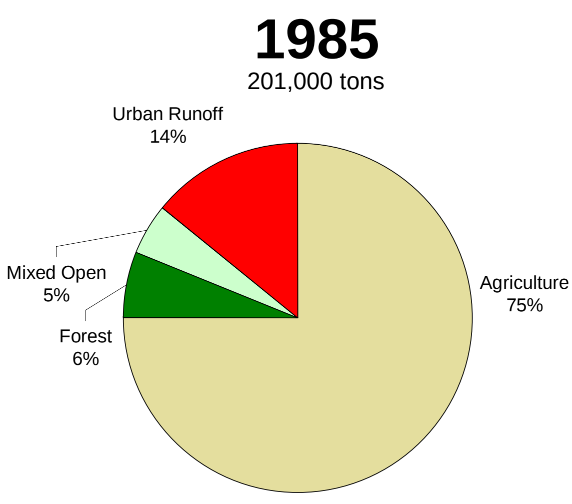


Phosphorus Contribution to Patuxent River by Source





Sediment Contribution to Patuxent River by Source



Overview of Monitoring Results

Water and Habitat Quality

Continuous Water Quality Monitoring Data

Continuous monitoring data have been collected from 2003 to the present at seven stations in the Patuxent—Iron Pot Landing at Western Branch, Mataponi Creek, Jug Bay, King's Landing, Benedict, Pin Oak Farm and Chesapeake Biological Laboratory. These data on dissolved oxygen, water temperature, salinity, pH, turbidity, and fluorescence (which estimates algae levels) were collected every 15 minutes during the warmer months giving a picture of daily and tidal changes in water quality. View these current data as well as archived data on our Eyes on the Bay website at **www.eyesonthebay.net.**

Water Quality Mapping Data

Water quality mapping data were collected from April to October 2003. These data on dissolved oxygen, water temperature, salinity, pH, turbidity, and fluorescence are collected every four seconds from a moving boat traveling throughout the Patuxent River. The thousands of data points collected are interpolated to provide maps of the water quality levels to see the spatial variability throughout the Patuxent. View maps of these data on our Eyes on the Bay website at **www.eyesonthebay.net.**

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at: **http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html**
MBSS also reports stream quality information summarized by county at: **http://www.dnr.state.md.us/streams/mbss/county_pubs.html** In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss.**

Montgomery County's Department of Environmental Protection posts information on their Countywide Stream Protection Strategy at:
http://www.montgomerycountymd.gov/siteHead.asp?page=/mc/services/dep/index.html.

Information on Prince George's County water quality monitoring and stream assessments are available at:
http://www.co.pg.md.us/Government/AgencyIndex/DER/PPD/Environment_Protection/water_quality.asp?h=20&s=40&n=50&n1=150

Water quality information collected by Maryland's volunteer Stream Waders is available at:
http://www.dnr.state.md.us/streams/mbss/mbss_volun.html

Long-term Water Quality Monitoring

Good water quality is essential to support the animals and plants that live or feed in the Patuxent tributaries. Important water quality parameters are measured at 14 long-term monitoring stations in the Patuxent basin. Parameters measured include nutrients, algal abundance, total suspended solids, water clarity (Secchi depth), and dissolved oxygen.

Linear trends are determined using a non-parametric test for trend (the Seasonal Kendall test) and percent change is determined using Sen's Slope. For a detailed description of the methods used to determine trends, see
http://www.dnr.state.md.us/Bay/tribstrat/status_trends_methods.html.

Total nitrogen, total phosphorus, algae, and total suspended solids levels have not improved signficantly during the recent (1995-2004) period, with the exception of the Lower Marlboro station. Water clarity worsened at many stations, and dissolved oxygen worsened at Nottingham. Looking at nonlinear trends over the longer term picture (1985-2004) is disheartening. Significant nonlinear nitrogen, phosphorus and water clarity trends at most stations indicate that although nutrient levels improved in the earlier part of the time period, they have leveled off or even worsened in recent years. However, improving nonlinear trends for algae levels occurred at three tidal fresh stations. See Figures PXT7-PXT12.

A water quality criteria document has been completed by the Chesapeake Bay Program—
http://www.chesapeakebay.net/baycriteria.htm—and new water quality criteria (for dissolved oxygen, water clarity, and chlorophyll) are currently being developed by the Maryland Department of the Environment—
http://www.mde.state.md.us/ResearchCenter/Data/waterQualityStandards/index.asp. When the new water quality critieria have been approved and the Patuxent River has been assessed, the results will be included in the basin summary.

Figure PXT7 – Total Nitrogen Concentrations in the Patuxent River Basin

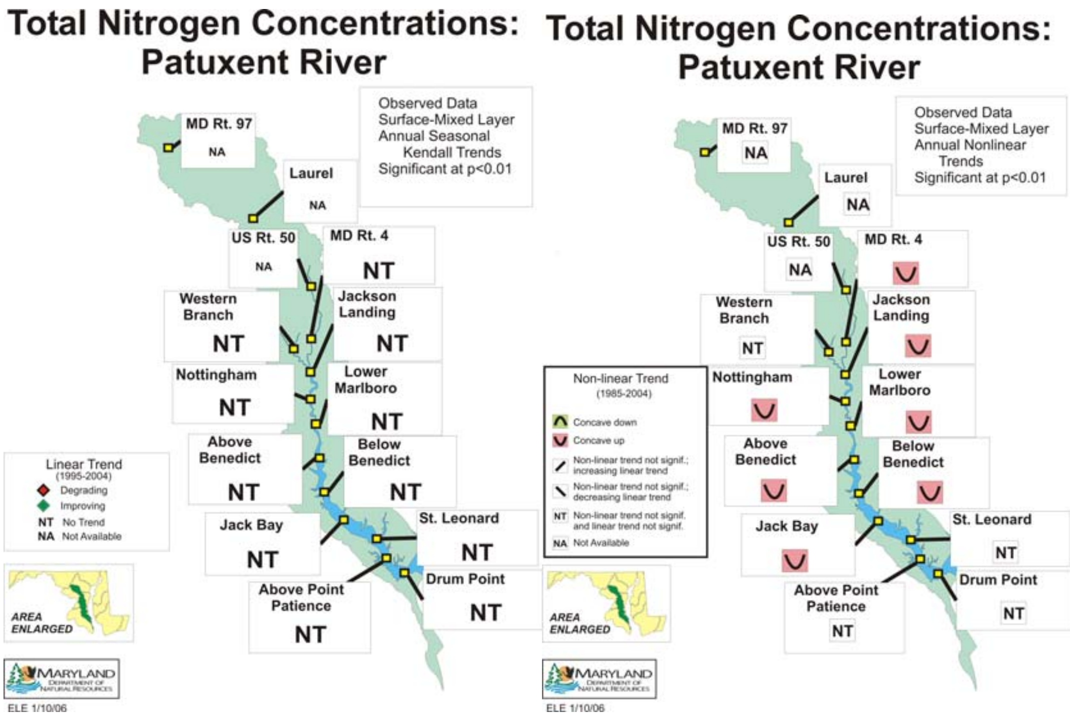


Figure PXT8 – Total Phosphorus Concentrations in the Patuxent River Basin

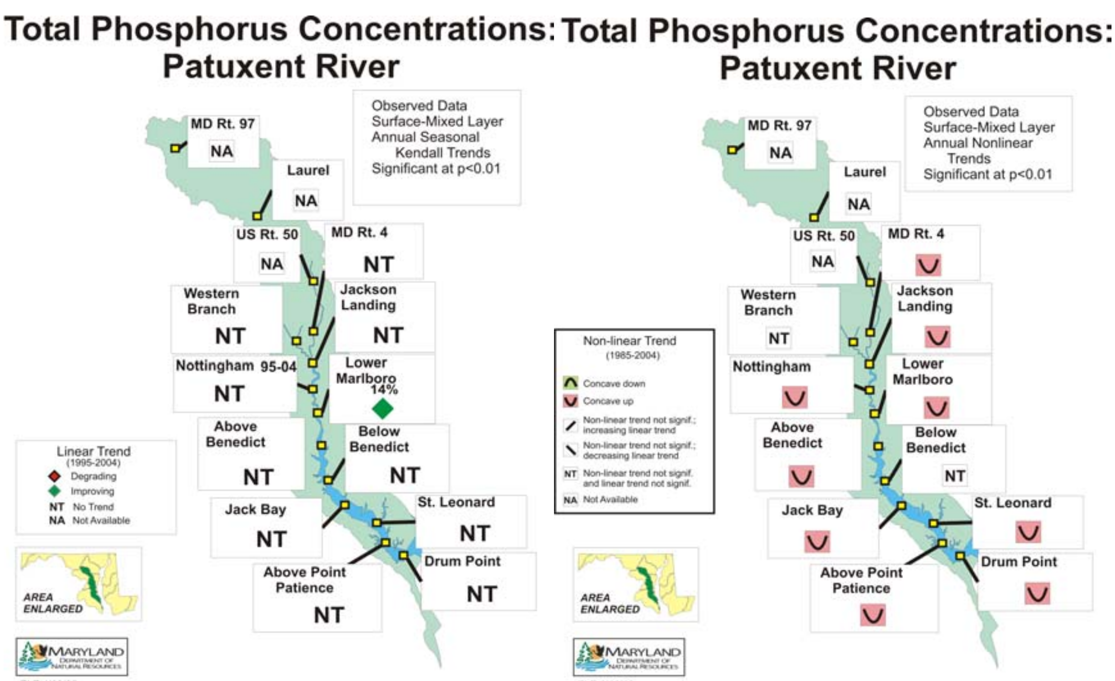


Figure PXT9 – Abundance of Algae in the Patuxent River Basin

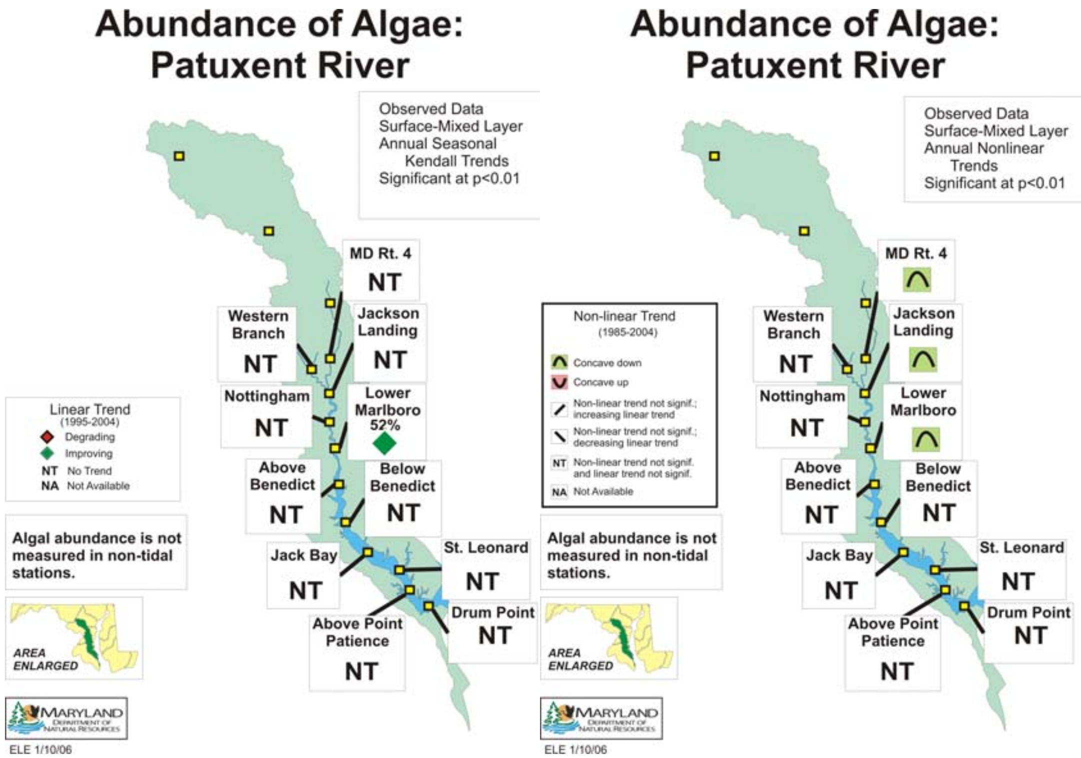


Figure PXT10 – Total Suspended Solids Concentrations in the Patuxent River Basin

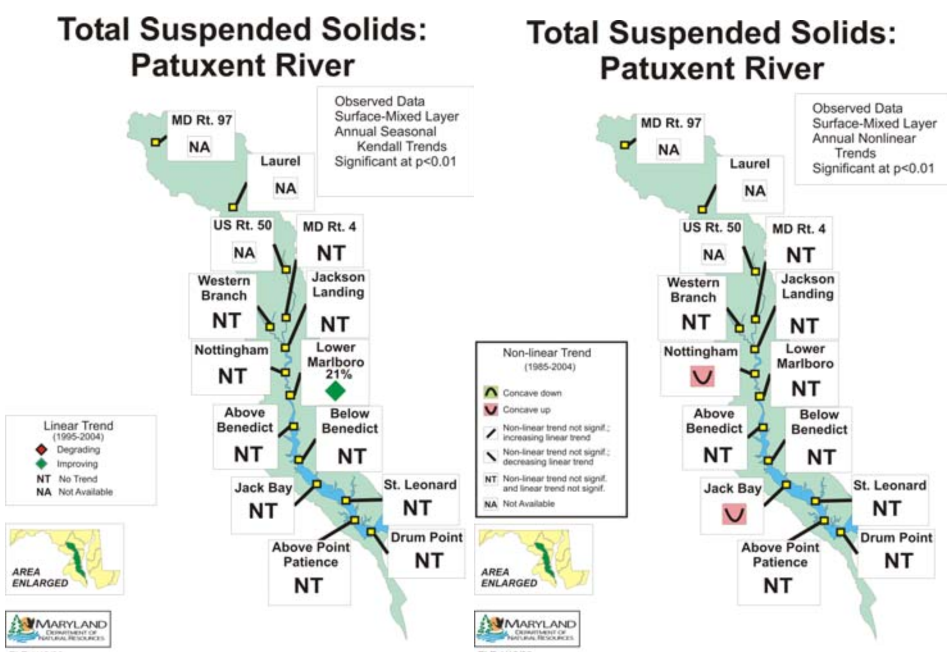


Figure PXT11 – Water Clarity (Secchi Depth) in the Patuxent River Basin

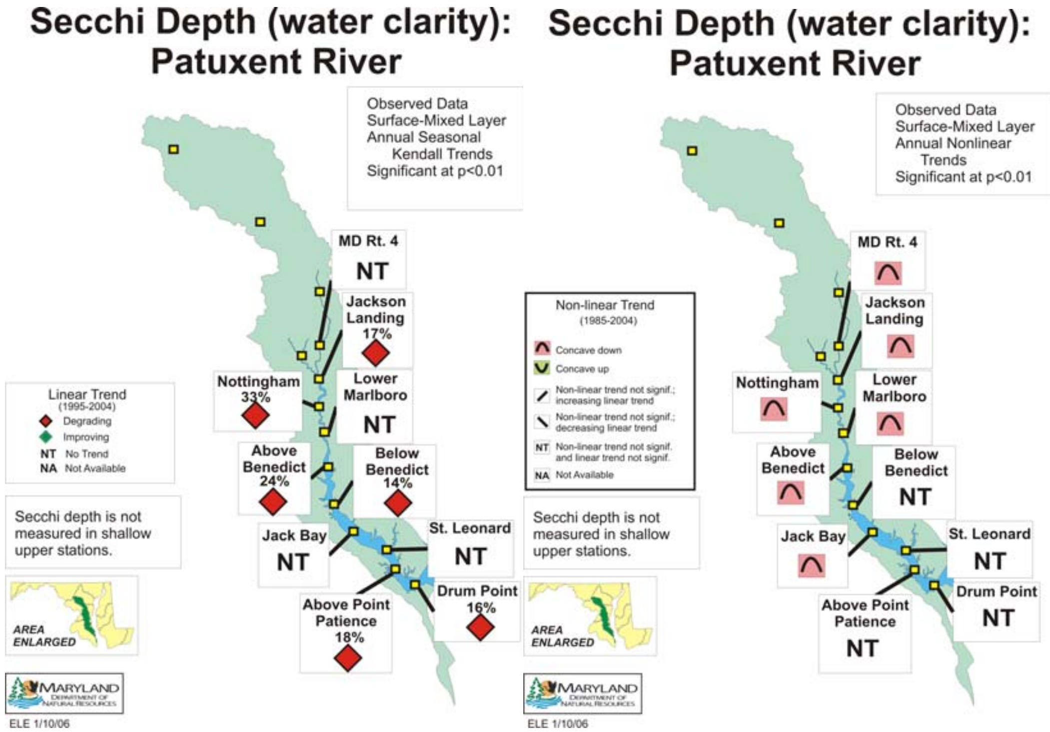
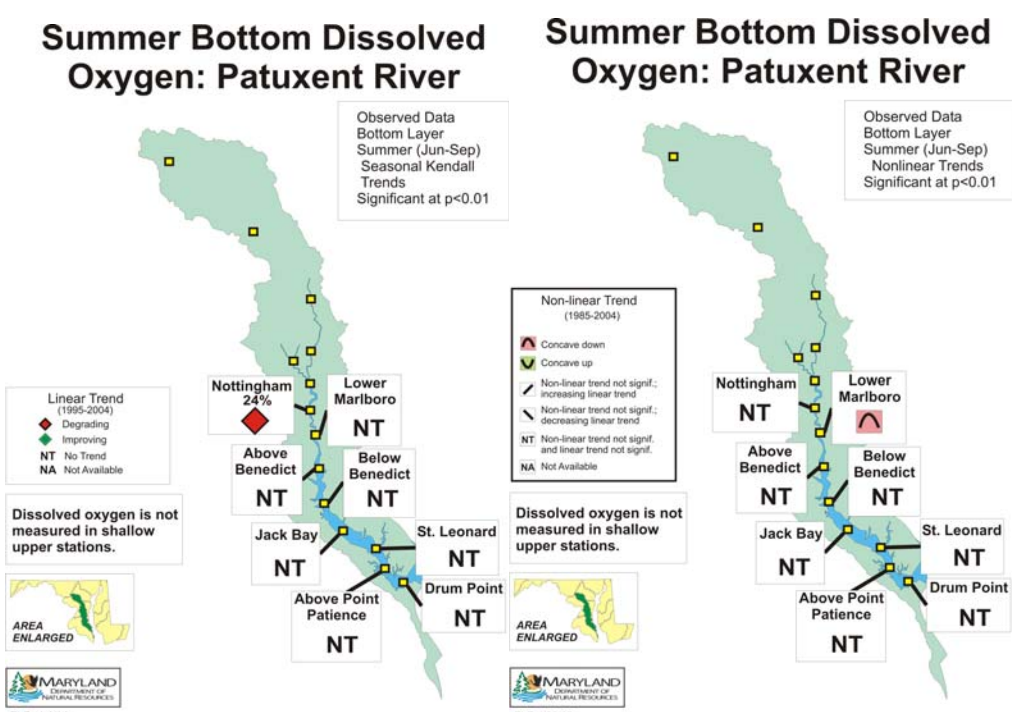


Figure PXT12 –Dissolved Oxygen in the Patuxent River Basin



Bay Grasses (Submerged Aquatic Vegetation—SAV)

The well defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl depend on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The "Percent Light at Leaf" habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older "Habitat Requirements" of five water quality parameters are still used for diagnostic purposes.

The tidal fresh Patuxent River has seen a remarkable growth of SAV since 1993 (www.vims.edu/bio/sav/). In fact, 1993 to 1998 saw the SAV coverage exceeding the revised goal of five acres, and 1994 to 1998 the SAV abundance was a factor of 20 over the goal (Figure PXT13). However, due to weather delays, the aerial survey was not able to cover the upper Patuxent in 1999. The 2003 aerial survey indicated there were 217 acres of SAV, the most ever recorded and 4340 percent of the revised goal. Ground-truthing by Maryland Department of Natural Resources, Patuxent River Park, Jug Bay Wetlands Sanctuary and citizens has found 16 species of SAV in this region with the most commonly identified ones being hydrilla (*Hydrilla verticillata*), common waterweed (*Elodea canadensis*), and coontail (*Ceratophyllum demersum*).

There are five long-term water quality-monitoring stations in this area (TF1.3, near the Route 4 bridge; TF1.2 at the confluence of Western Branch; WXT0001 near the Western Branch Waste Water Treatment Plant; TF1.4, Jackson Landing near the ruins of the old railroad bridge at Jug Bay Wetlands Sanctuary; and TF1.5, Nottingham near the confluence of Kings Creek). The data from these sources indicate that most SAV habitat requirements fail for this region (percent light at leaf, light attenuation, concentration of suspended solids and phosphorus), with only algae levels passing (nitrogen levels are not applicable to the tidal fresh regions) (Figure PXT14). The most likely explanation for the growth of SAV even though there are poor water quality conditions is that the plants are growing on very shallow mudflats, which provides them with enough light to grow. Wild celery (*Vallisneria americana*) transplants conducted in 1999 and 2000 near the Jackson Landing launch ramp at Patuxent River Park have performed well (www.dnr.state.md.us/bay/sav/jug_bay.html). In spring of 2000, there were approximately 16 square meters of plants that survived the winter from the 1999 plantings, and the year 2000 transplants had approximately 65 percent survival. There was evidence of the plants successfully flowering and producing seeds, in addition to tubers (overwinter structures), which will hopefully lead to increased natural recovery in the future. Transplants in 2001 and 2002 and regrowth from previous years did not fare as well. Although there was excellent growth of the planting area through late summer, hydrilla smothered the wild celery plants in the fall. Plants have not reappeared.

The middle Patuxent area has also seen remarkable re-vegetation in recent years as mapped by the Virginia Institute of Marine Science annual aerial survey. (www.vims.edu/bio/sav/). Beginning in 1994, when SAV first reappeared in this region with 53 acres, the SAV coverage increased to 106 acres in 2003 and 2004, or 156 percent of the revised goal (68 acres) (Figure PXT13). Ground-truthing by Maryland Department of Natural Resources, Patuxent River Park, and citizens have found 12 species of SAV in this region with the most commonly identified ones being coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), and curly pondweed (*Potamogeton crispus*).

There are two long-term water quality monitoring stations in this area: TF1.6, Lower Marlboro near Short Point; and TF1.7, Above Benedict just north of Cedarhaven. The water quality data from these sites indicates that this region fails most SAV habitat requirements (percent light at leaf, light attenuation, suspended solids, nitrogen, and phosphorus concentrations), with only algae levels passing (Figure PXT14).

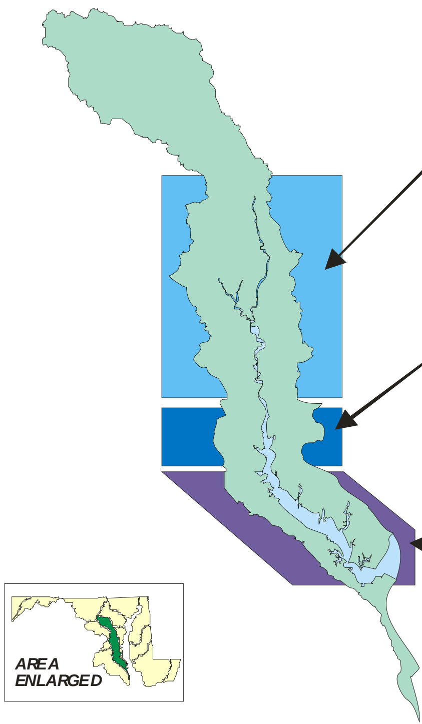
The lower Patuxent River has not had a recovery similar to the upper two reaches. The Virginia Institute of Marine Science annual aerial survey (www.vims.edu/bio/sav/) has found only very small SAV beds (less than 25 acres) since 1987 (Figure PXT13), though 2002 had 140 acres. This is well below the revised SAVgoal of 1,325 acres. There were 42 acres of SAV in 2004. The few beds that have been found in the last five years were in the Solomons Island and Hungerford Creek areas. Ground-truthing by citizens, National Oceanic and Atmospheric Administration, Environmental Protection Agency, Chesapeake Biological Laboratory and Patuxent River Park staff has found (in order of frequency) horned pondweed (*Zannichellia palustris*), sago pondweed (*Potamogeton pectinatus*), milfoil (*Myriophyllum spicatum*), widgeon grass (*Ruppia maritima*), wild celery (*Vallisneria americana*) and common waterweed (*Elodea* sp.).

There are five long-term water quality monitoring stations in this reach of the Patuxent River: RET1.1, Below Benedict located near Long Point; LE1.1, Jack Bay; LE1.2 at the mouth of St. Leonard's Creek; LE1.3, Above Point Patience at the mouth of Cuckold Creek; and LE1.4 between Drum and Fishing Points. Data from these stations indicate that suspended solids, algae, nitrogen and phosphorus levels and light attenuation all pass the SAV habitat requirements (Figure PXT14). Percent light at leaf is borderline relative to the habitat.

Several large-scale eelgrass restoration projects occurred in the lower Patuxent in 2004 and 2005. Eelgrass seed was distributed over 3.3 acres near the Chesapeake Biological Laboratory pier, 2.9 acres at Myrtle Point, 0.75 acre at the mouth of Hungerford Creek and approximately 10 acres at Parran's Hollow, just north of Jefferson Patterson Park. Additionally, small adult shoot test plots were installed at each of these locations. Intensive monitoring of recruitment and survival has occurred throughout 2005 and additional monitoring will occur in 2006.

Figure PXT13 –Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Patuxent Basin

SAV Distribution: Patuxent River



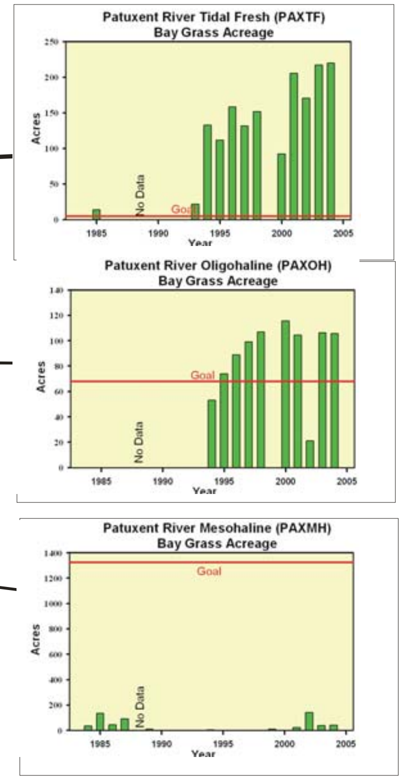


Figure 1: SAV coverage in Patuxent River, 1984 to 2004

Figure PXT14 –Bay Grasses (Submerged Aquatic Vegetation) Distribution in the Patuxent Basin

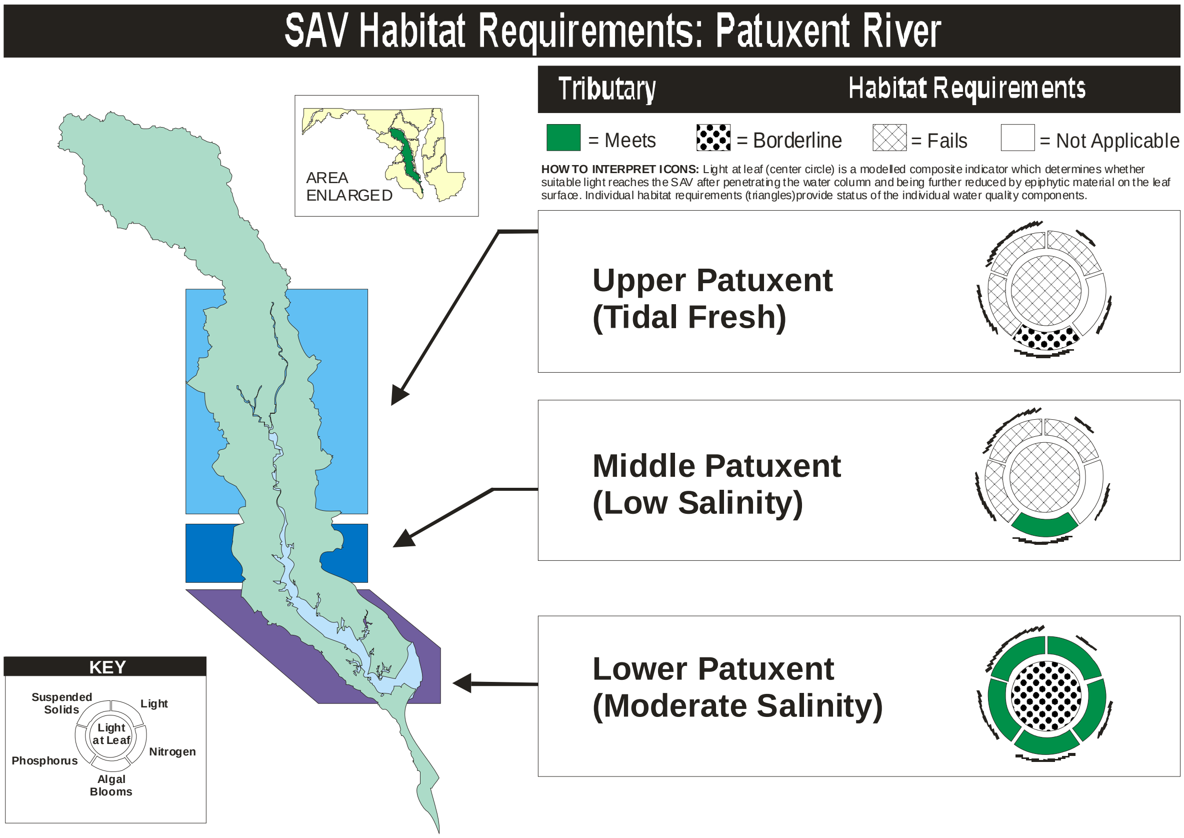


Figure 2: SAV habitat requirement attainment in Patuxent River

Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see http://esm.versar.com/Vcb/Benthos/backgrou.htm

During the period 1999-2003, benthic community condition in the Patuxent River was best in the oligohaline portion of the river, and worst in the tidal fresh and mesohaline regions (Figure PXT16). Benthic degradation in the Patuxent River is mainly related to adverse effects from low dissolved oxygen. The intensity of summer hypoxic events varies annually, and this variability is reflected in the B-IBI. In the mesohaline Patuxent River, and over the 1995-2003 time series, there was a positive relationship between the percentage of samples failing the restoration goals (B-IBI < 3) and the frequency of low dissolved oxygen observations below 2 mg/L (Figure PXT15). Degradation was due primarily to low abundance, biomass, and species diversity, and to low biomass of pollution-sensitive species. Pollution-sensitive species are typically representative of mature communities in the absence of low dissolved oxygen stress. One factor linked to hypoxia is the amount of decaying organic matter from algae blooms. Large algae concentrations are likely to result in more extensive hypoxia and increased benthic degradation. Consistent with poor water clarity and high algae concentrations, the lower Patuxent River shows a positive relationship between the

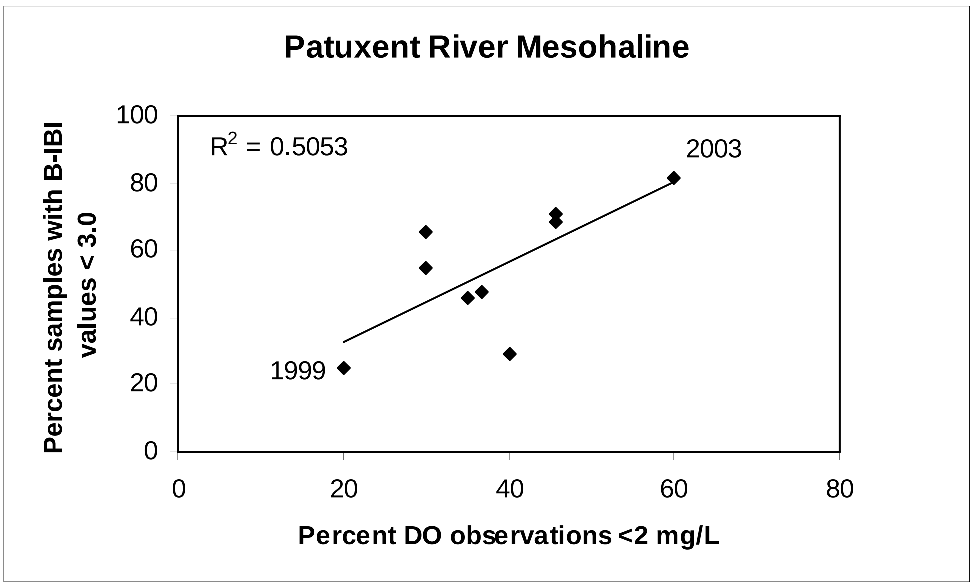


Figure PXT15. Relationship of benthic index of biotic integrity to percent dissolved oxygen observations below 2 mg/L (June-September) in the mesohaline Patuxent River. Each point represents a different year, 1995-2003. Dissolved oxygen data are fortnight near-bottom observations from Chesapeake Bay Water Quality Monitoring program stations RET1.1, and LE1.1 through LE1.4.

percentage of samples with severely degraded benthic condition and average chlorophyll concentrations below the pycnocline (Llansó et al. 2004).

Benthic community status at Patuxent River fixed monitoring stations showed degraded conditions at Lyons Creek and Broomes Island in 2003, and good condition at Holland Cliff and Chalk Point (Figure PXT17). At Holland Cliff, the magnitude of a degrading trend in the B-IBI continued to diminish with the 2003 data, giving signals of recovery at this station. In addition, a previous degrading trend through 2001 at Broomes Island was no longer significant in 2002 and 2003. Variable annual low dissolved oxygen events are likely to influence trend direction at this station. Station 74 is under the thermal influence of the Chalk Point power plant. However, no significant impacts on benthos from the thermal discharge have been documented to date. Likewise, an oil spill in Swanson Creek in April 2000 did not show impacts at the Chalk Point fixed station.

Figure PXT16. Total number of sites, degraded sites, and probabilities (90% confidence limits) of observing degraded benthos, non-degraded benthos, or benthos of intermediate condition (indeterminate for low salinity habitats) for the Patuxent River Basin, 1999-2003.

Segment	Tributary	Total No. Sites	No. Deg. Sites	P Deg.	P Non-deg.	P Interm.
PAXTF	Patuxent tf.	5	3	55.6 (28.2–85.9)	22.2 (0–45.1)	44.4 (17.1–71.8)
PAXOH	Patuxent olg.	13	3	29.4 (11.2–47.6)	47.1 (27.1–67.0)	35.3 (16.2–54.4)
PAXMH	Patuxent mes.	107	51	47.7 (39.9–55.6)	35.1 (27.7–42.6)	18.9 (12.8–25.1)

Figure PXT17. Trends in benthic community condition for Patuxent River Basin fixed stations, 1985-2003. Trends were identified using the van Belle and Hughes (1984) procedure. Current mean B-IBI and condition based on 2001-2003 values. Initial mean B-IBI and condition based on 1985-1987 values. NS: not significant.

Station[1]	Trend Significance	Median Slope (B-IBI units/yr)	Current Condition (2001-2003)	Initial Condition (1985-1987)
79, Lyons Creek	NS	0.00	2.39 (Degraded)	2.75 (Marginal)
77, Holland Cliff	$p < 0.1$	–0.07	3.40 (Meets Goal)	3.76 (Meets Goal)
74, Chalk Point	NS	0.00	3.44 (Meets Goal)	3.78 (Meets Goal)
71, Broomes Island	NS	0.00	2.33 (Degraded)	2.59 (Degraded)

[1]Sta. 79, tidal freshwater, 38.750448 lat., 76.689020 long.
Sta. 77, low mesohaline, 38.604452 lat., 76.675017 long.
Sta. 74, low mesohaline, 38.547288 lat., 76.674851 long.
Sta. 71, high mesohaline mud, 38.395124 lat., 76.548844 long.

For information on benthic community health throughout the Bay, see the 2004 Long-term Benthic Level One Report ("Comprehensive Report") at http://www.esm.versar.com/Vcb/Benthos/referenc.htm.

Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as nutrients are available. If nutrients are limited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus. If one of the nutrients is not available in the adequate quantity, phytoplankton growth is limited by that nutrient. If both nutrients are available in excess, then the system is nutrient saturated.

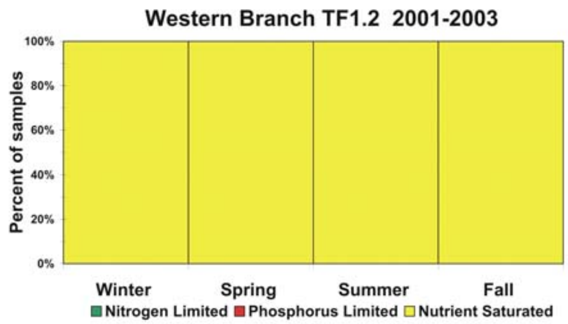
Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

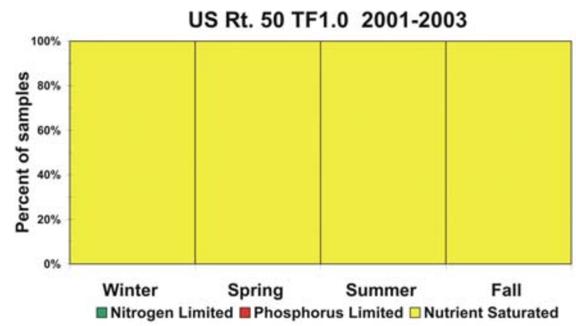
Phosphorus limitation occurs when there is insufficient phosphorus, i.e., there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are available to the estuary from stormwater flow.

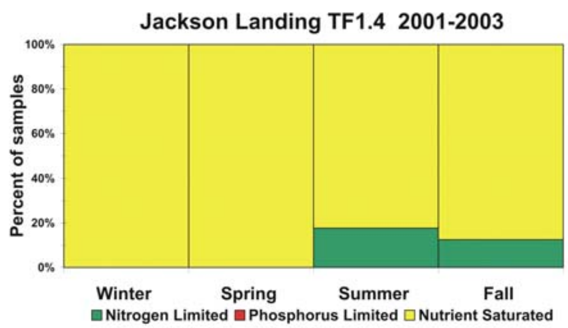
If an area is light or temperature limited, and both nitrogen and phosphorus are available in excess, then a situation of nutrient saturation occurs. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth. Light or temperature limitation occurs more frequently in upstream tidal fresh areas and turbidity maximum zones (light-limited because of higher turbidity) or in winter (inadequate light and temperature for some types of phytoplankton).

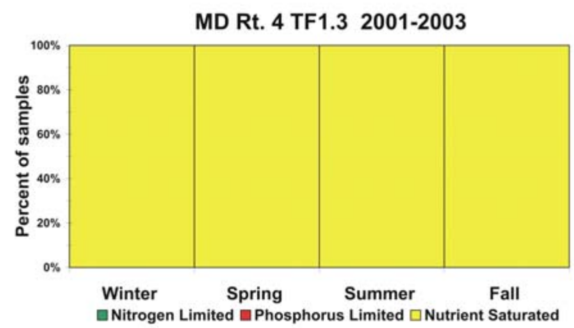
Managers can use these predictions based on monitoring information to assess what management approach will be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton grown. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area. When used along with other information available from the water quality and watershed management programs, nutrient limitation predictions form a valuable tool allowing managers to make more cost-effective management decisions.

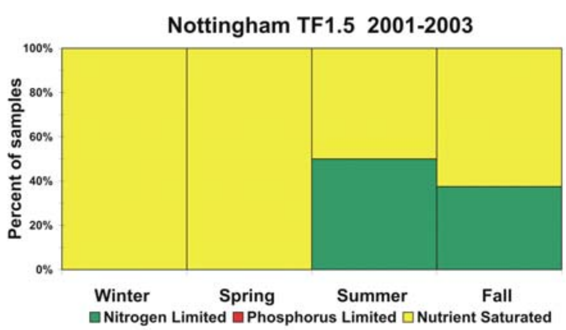
The nutrient limitation models were used to predict nutrient limitation for the stations in the Patuxent River. Results are summarized graphically for the most recent three-year period (2001-2003) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Overall, the upper river is largely nutrient saturated and seasonal patterns in nutrient limitation are controlled by riverflow (Fisher and Gustafson 2003). The lower river is largely nitrogen limited, probably due to sewage inflows with low Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratios and lower variability in seasonal river flows (Fisher and Gustafson 2003). For a text description of the information presented here graphically, see Appendix C.

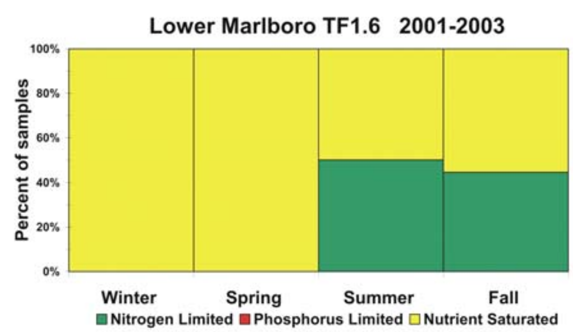


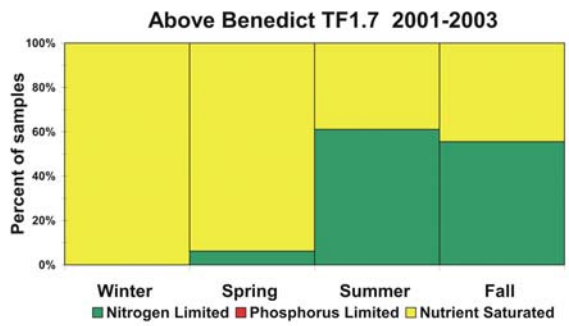


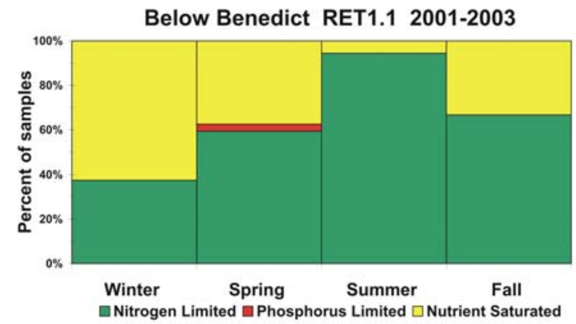


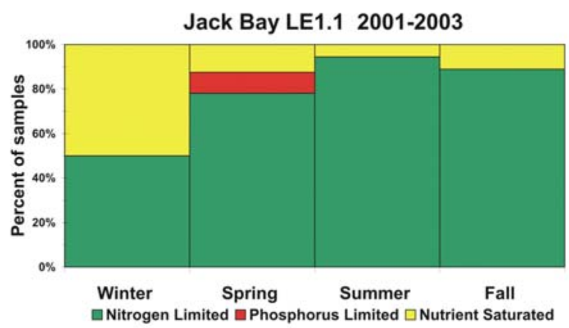


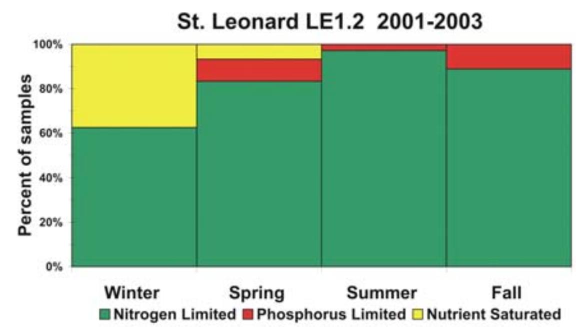


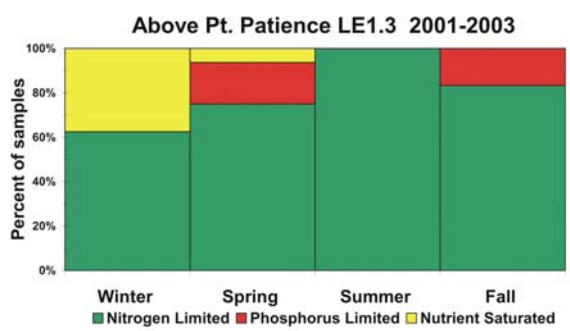


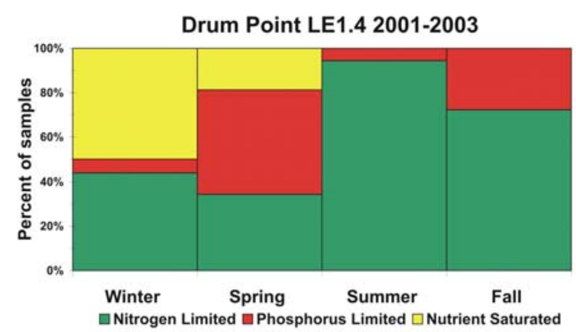

Above Benedict TF1.7 2001-2003
Percent of samples
100%
80%
60%
40%
20%
0%
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated


Below Benedict RET1.1 2001-2003
Percent of samples
100%
80%
60%
40%
20%
0%
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

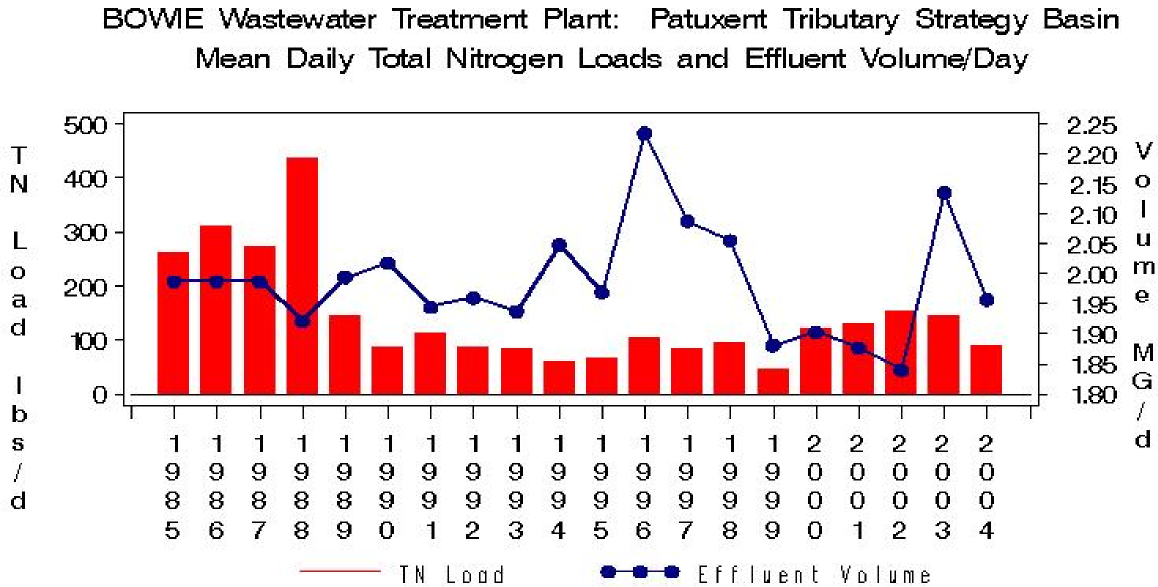

Jack Bay LE1.1 2001-2003
Percent of samples
100%
80%
60%
40%
20%
0%
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

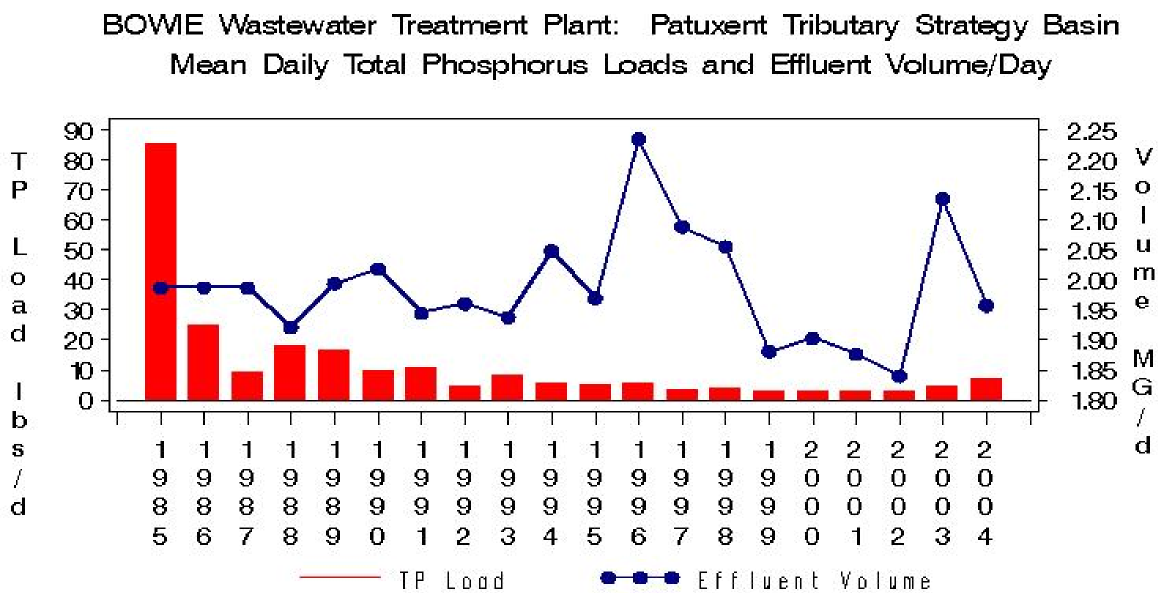

St. Leonard LE1.2 2001-2003
Percent of samples
100%
80%
60%
40%
20%
0%
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

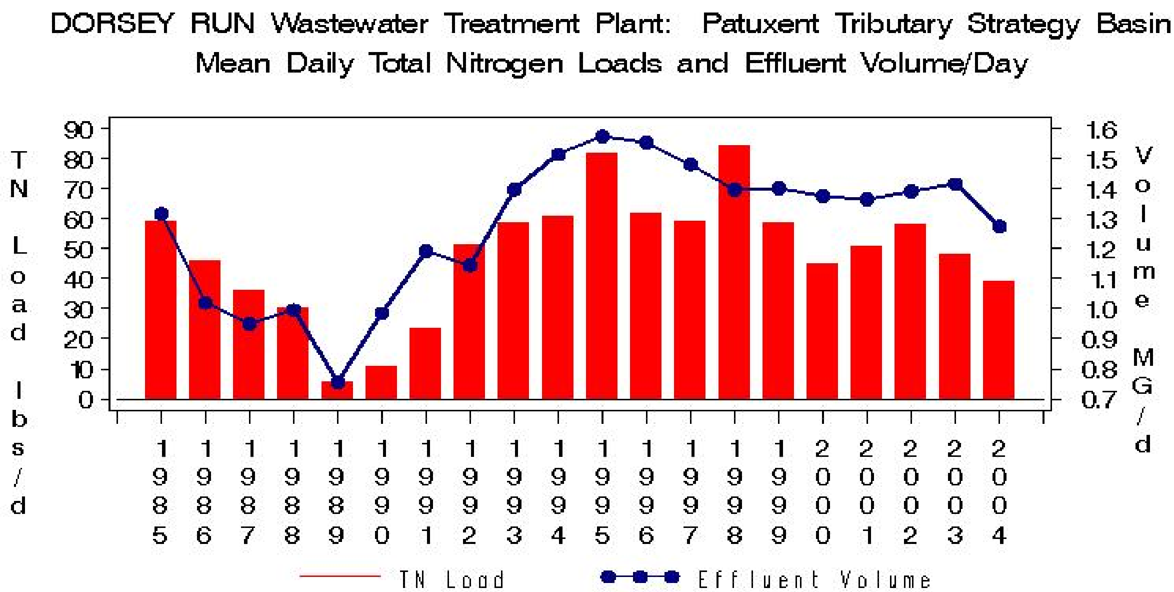

Above Pt. Patience LE1.3 2001-2003
Percent of samples
100%
80%
60%
40%
20%
0%
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

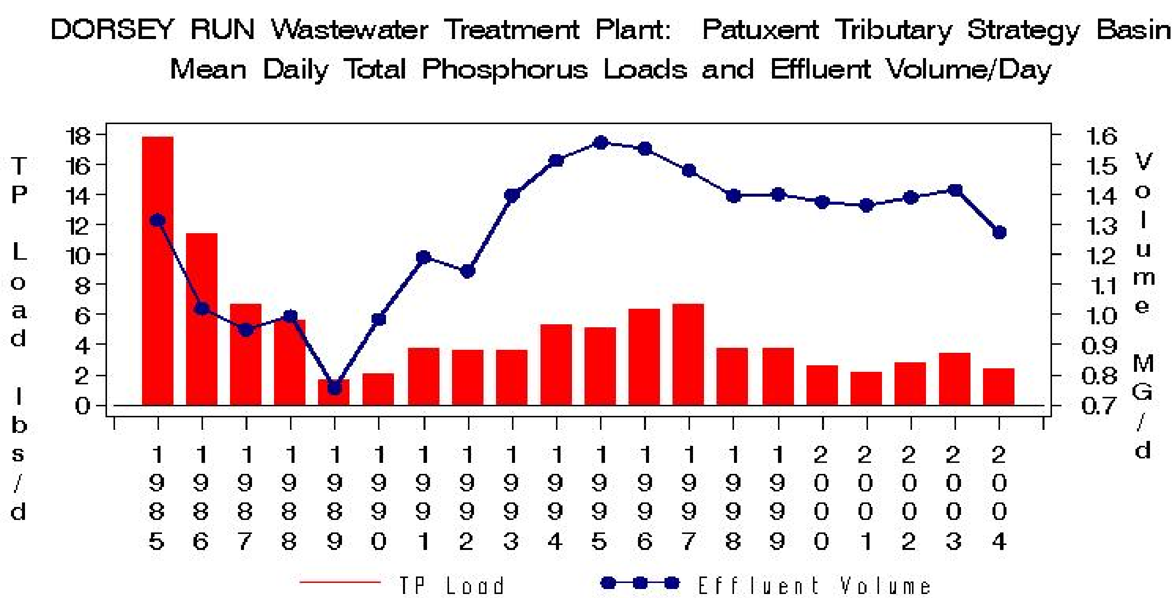

Drum Point LE1.4 2001-2003
Percent of samples
100%
80%
60%
40%
20%
0%
Winter
Spring
Summer
Fall
Nitrogen Limited
Phosphorus Limited
Nutrient Saturated

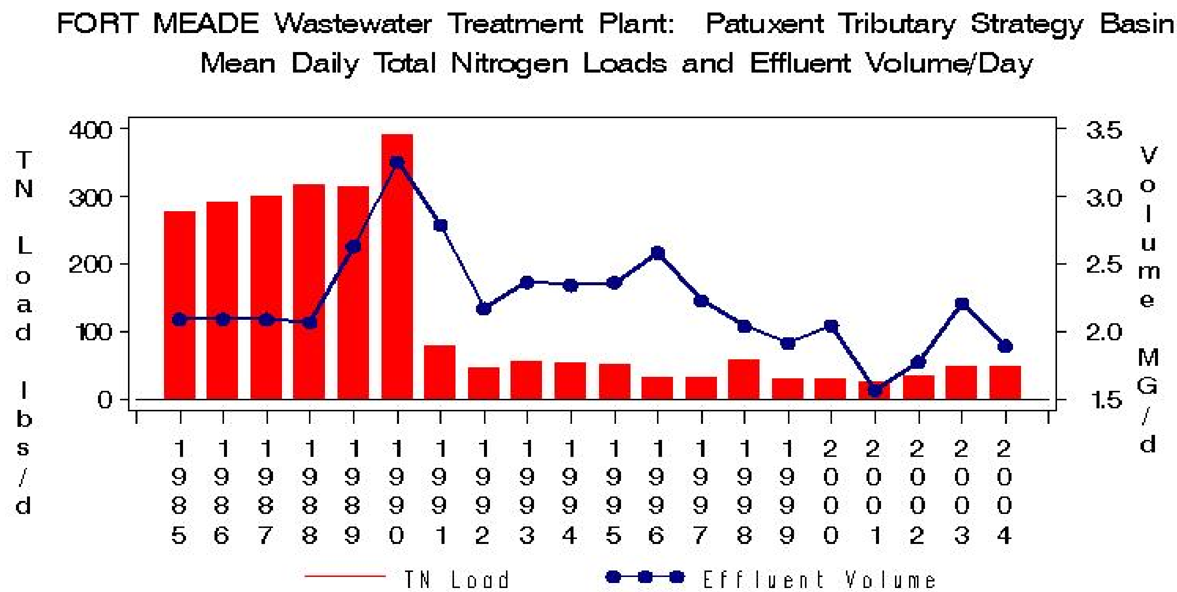
Appendix A – Nutrient Loadings from Major Wastewater Treatment Facilities in the Patuxent River Basin

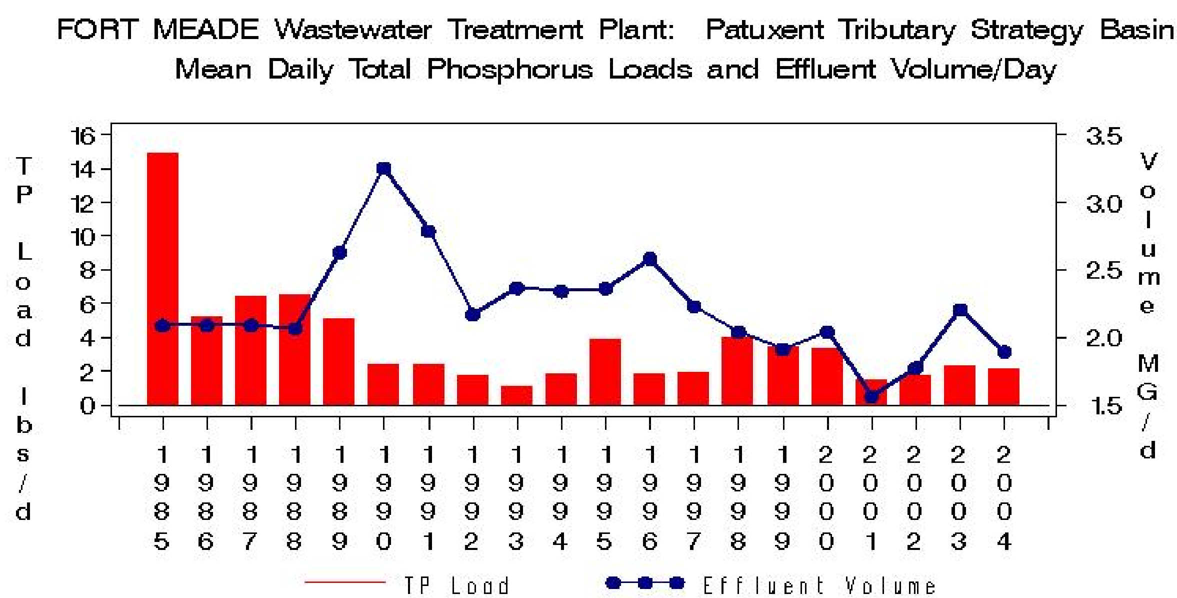


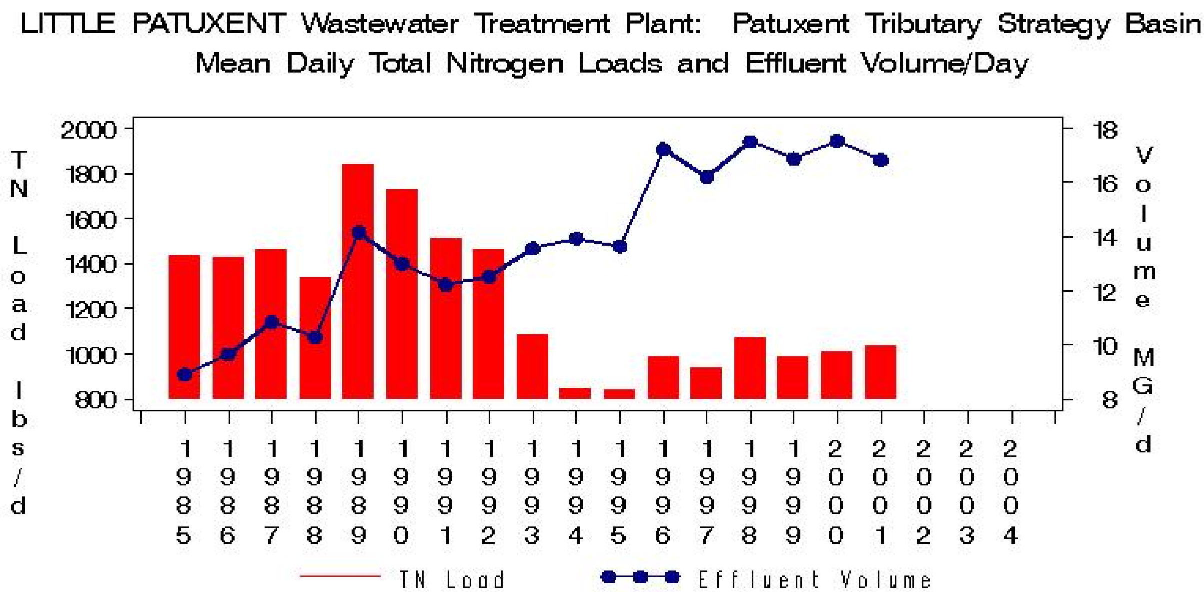


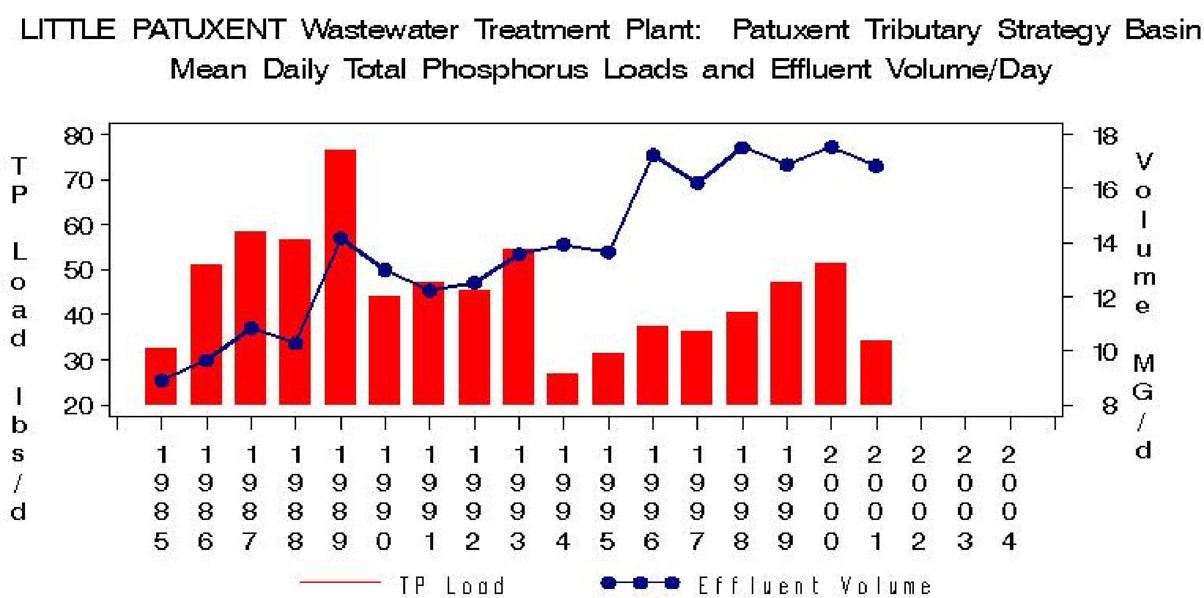

DORSEY RUN Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day
TN Load lbs/d
Volume MG/d
TN Load
Effluent Volume


DORSEY RUN Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Effluent Volume/Day
TP Load lbs/d
Volume MG/d
TP Load
Effluent Volume

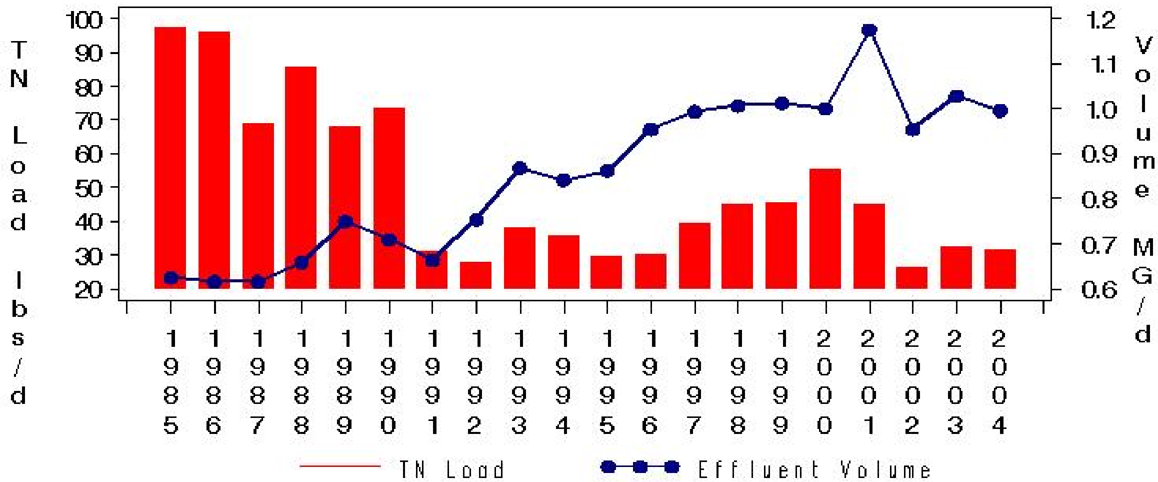

FORT MEADE Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day
TN Load lbs/d
Volume MG/d
TN Load
Effluent Volume


FORT MEADE Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Effluent Volume/Day
TP Load lbs/d
Volume MG/d
TP Load
Effluent Volume

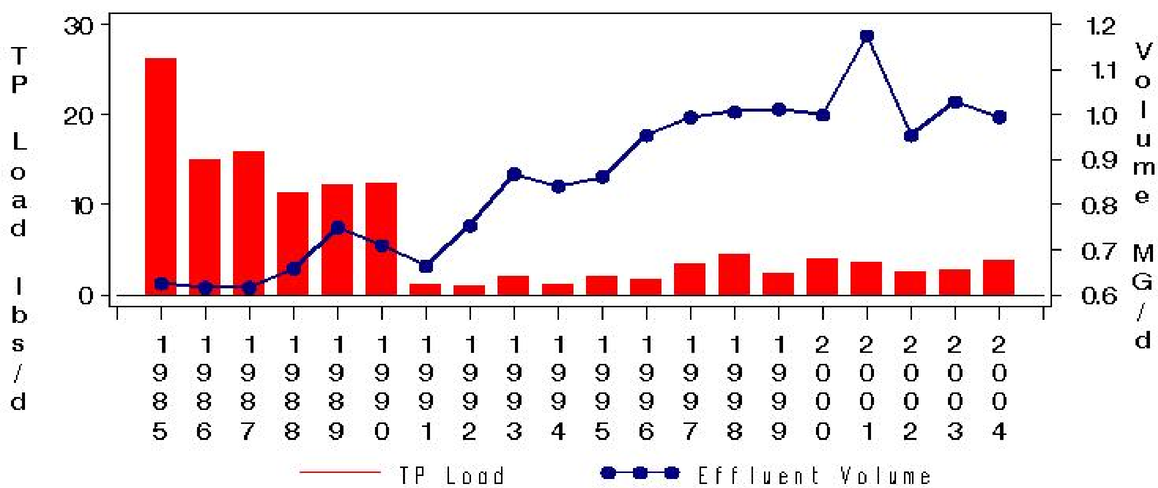

LITTLE PATUXENT Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day
TN Load lbs/d
Volume MG/d
2000
1800
1600
1400
1200
1000
800
18
16
14
12
10
8
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
TN Load
Effluent Volume


LITTLE PATUXENT Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Effluent Volume/Day
TP Load lbs/d
Volume MG/d
80
70
60
50
40
30
20
18
16
14
12
10
8
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
TP Load
Effluent Volume

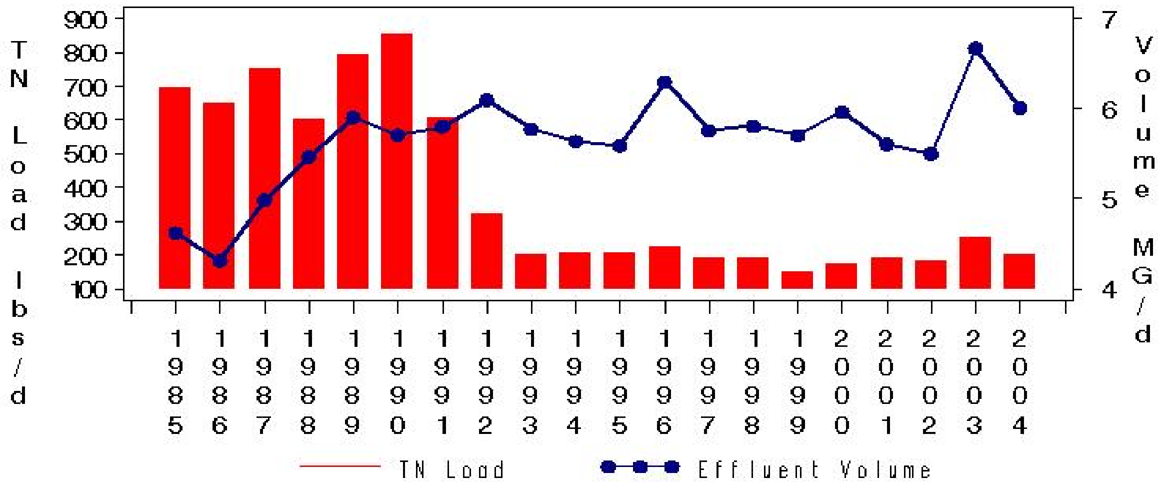
MARYLAND CITY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day



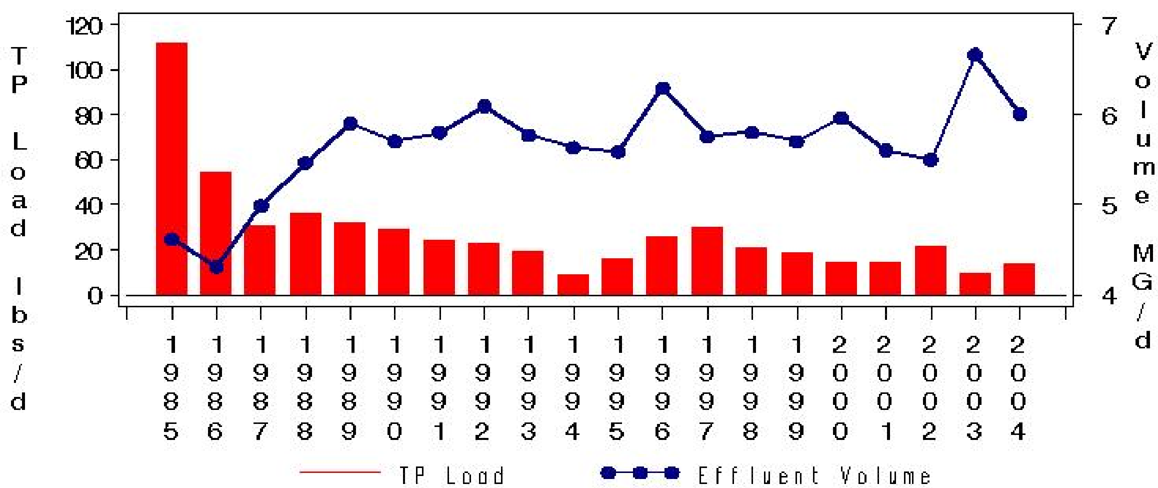
MARYLAND CITY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Effluent Volume/Day

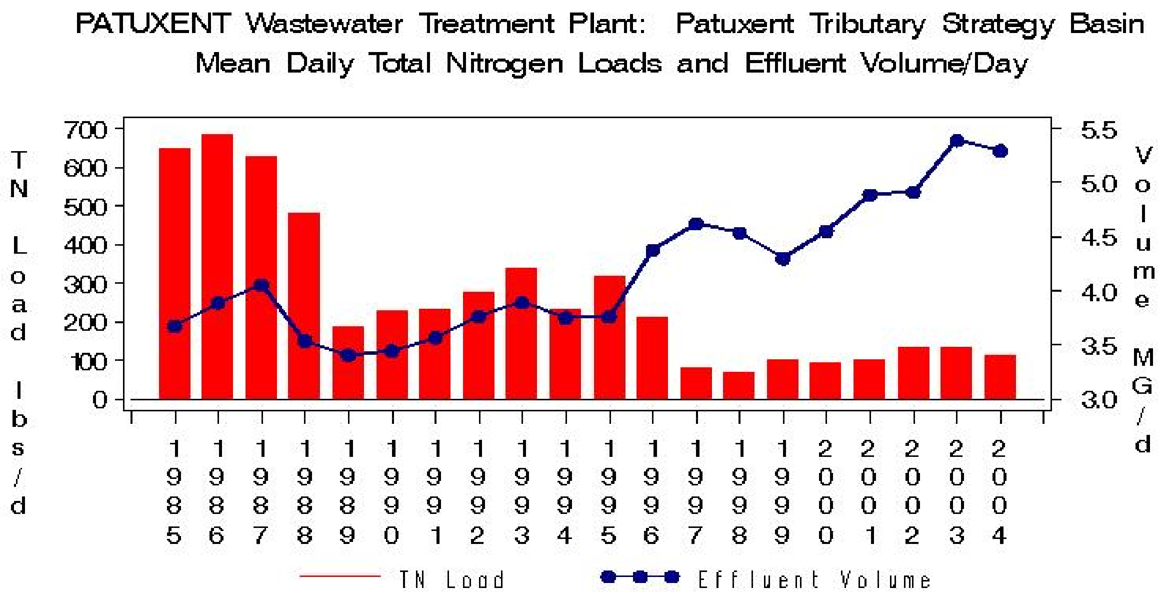


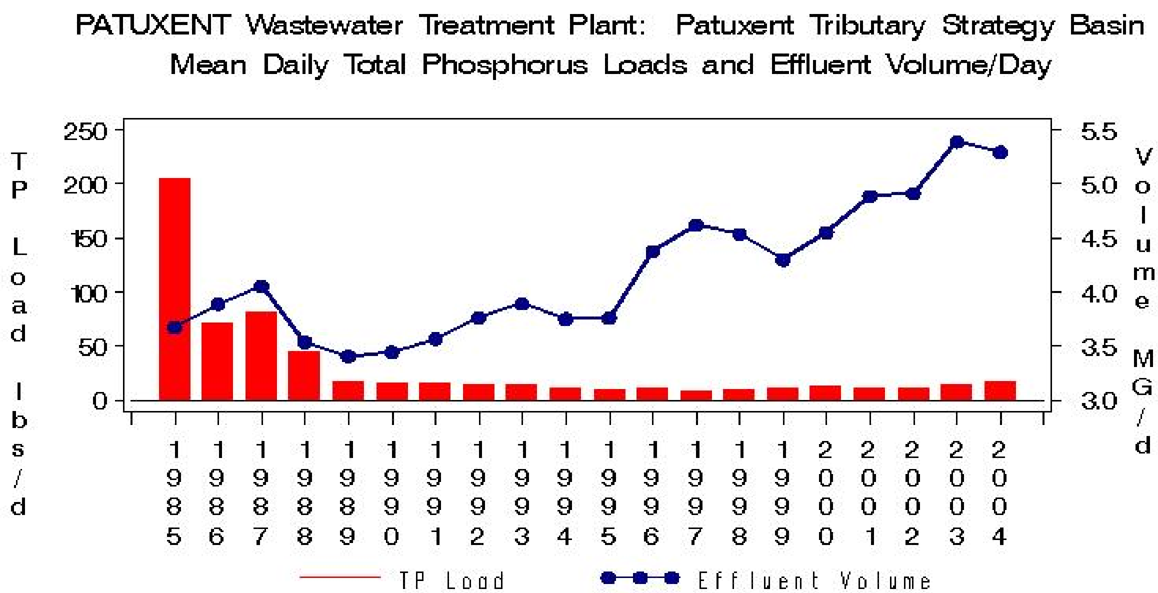
PARKWAY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day



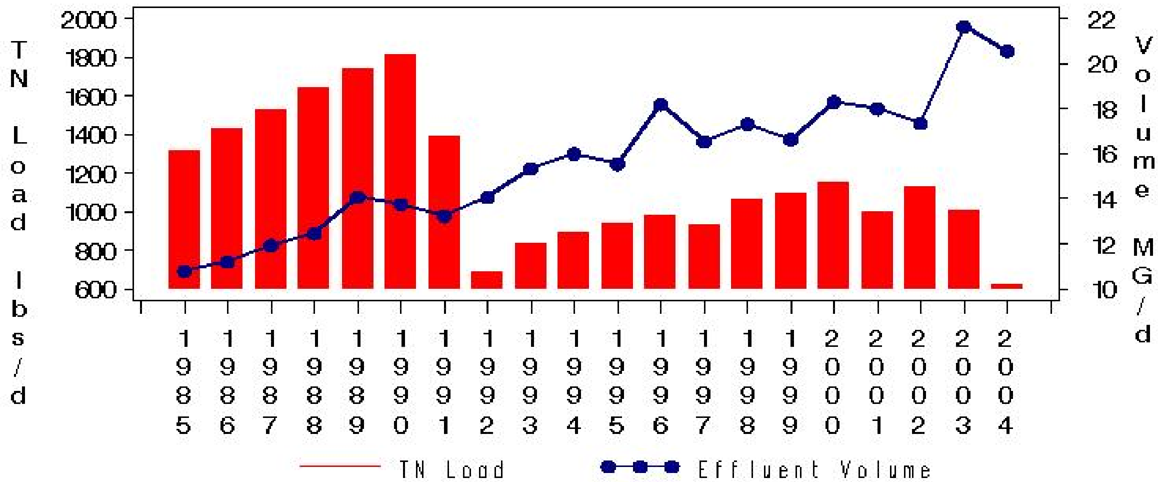
PARKWAY Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Effluent Volume/Day



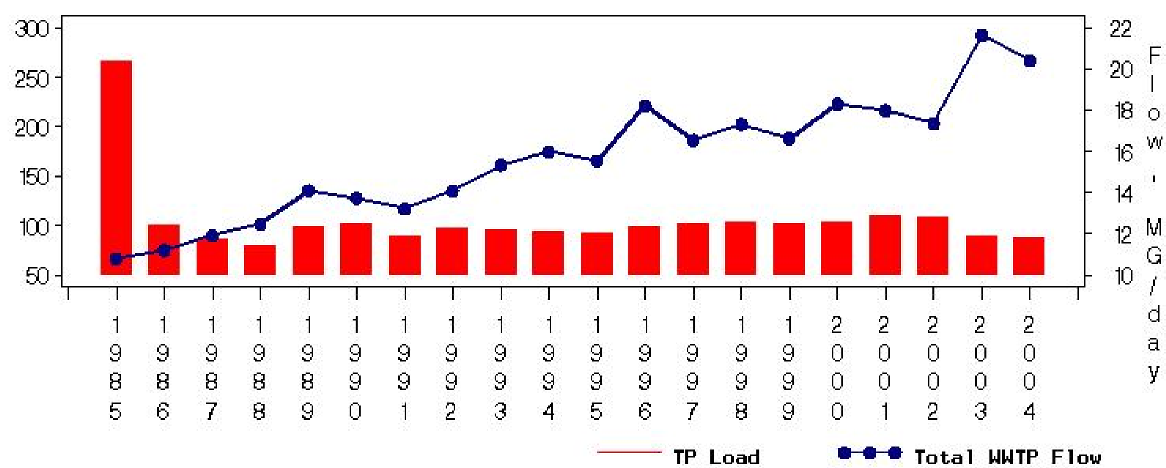

PATUXENT Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day
TN Load lbs/d
Volume MG/d
TN Load
Effluent Volume


PATUXENT Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Effluent Volume/Day
TP Load lbs/d
Volume MG/d
TP Load
Effluent Volume

WESTERN BRANCH Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Effluent Volume/Day



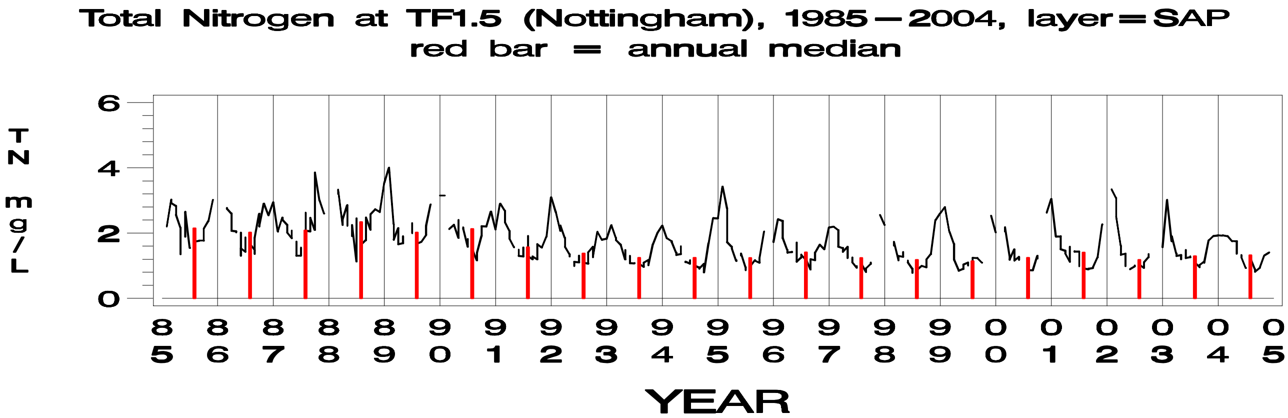
WESTERN BRANCH Wastewater Treatment Plant: Patuxent Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

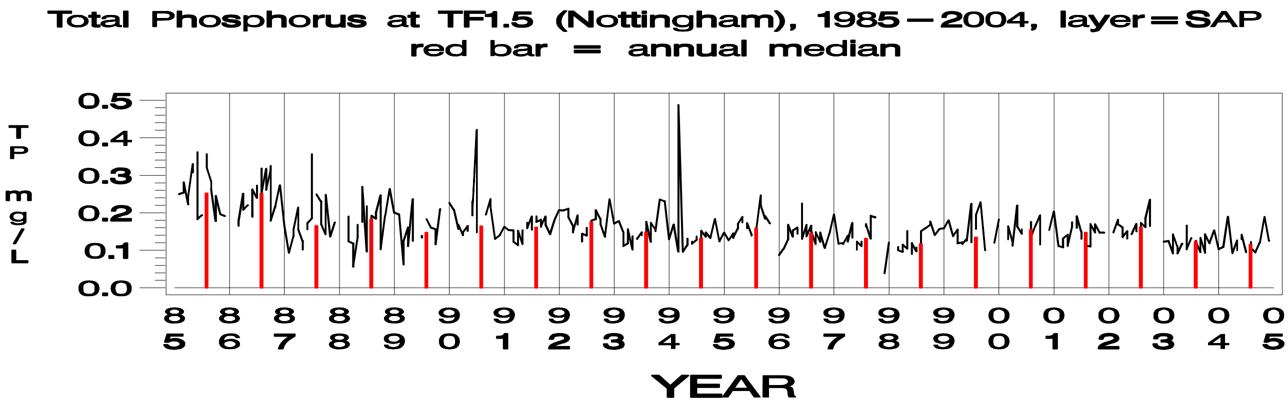


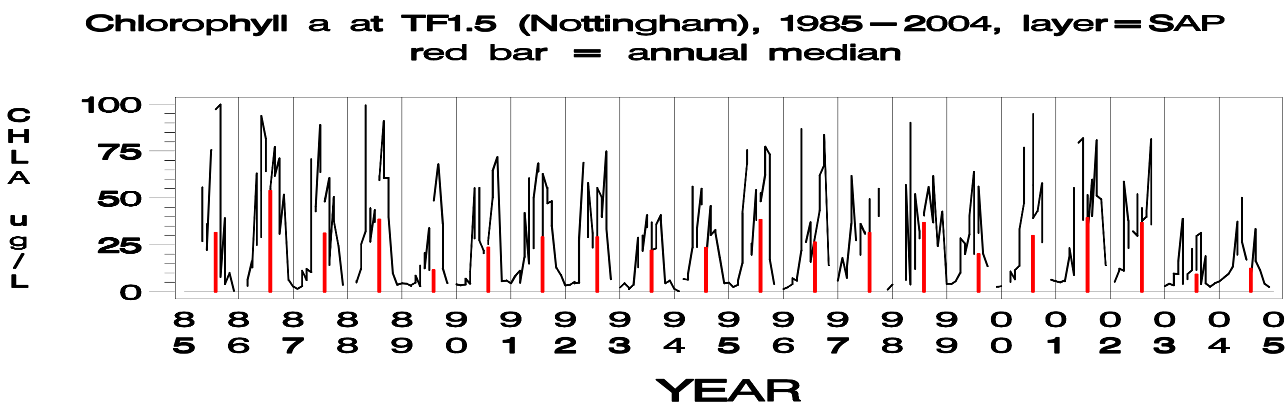
Appendix B – Long-term Tidal Water Quality Data

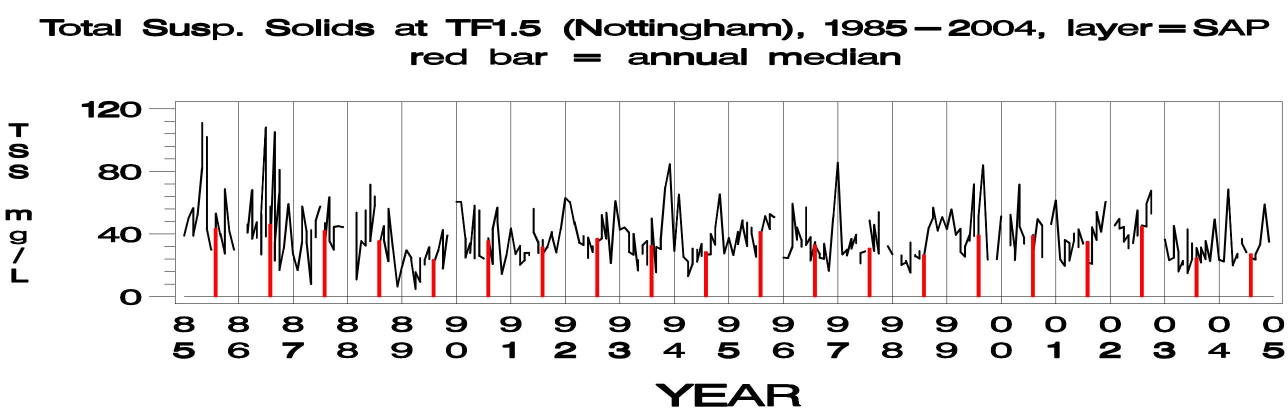
Water quality concentrations based on measured concentration data taken at long-term stations are graphed. Mean concentration for the surface and above-pycnocline data are shown for each sampling date on the black line. Annual medians are shown as red bars.

Note that parameter values tend to fluctuate highly from year to year, and much of this fluctuation can be attributed to flow conditions. For example, in high flow years (wet years), nutrient levels are higher than in dry years. Also, the timing of the spring freshet and other weather condtions can determine the strength and duration of the pycnocline, strongly affecting dissolved oxygen levels. Topography, hydrogeology, stream hydrology, how a basin is developed, and management actions all affect the influence of weather conditions.

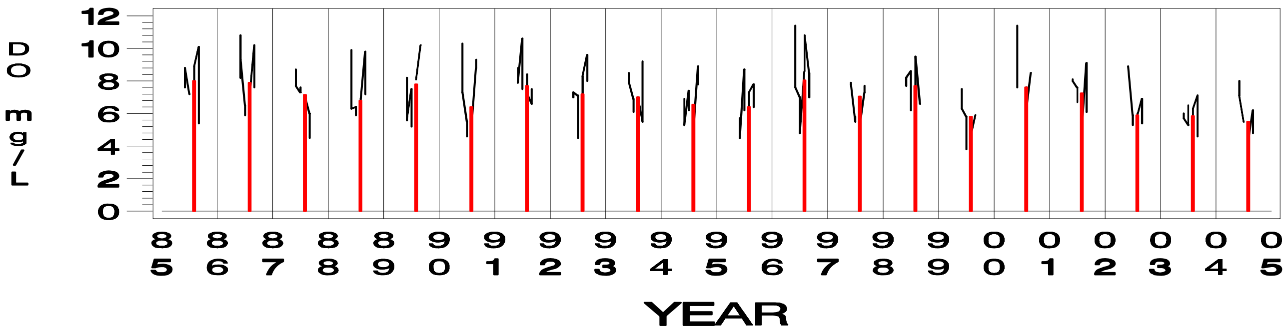

Total Nitrogen at TF1.5 (Nottingham), 1985-2004, layer=SAP
red bar = annual median
TN mg/L
YEAR


Total Phosphorus at TF1.5 (Nottingham), 1985-2004, layer=SAP
red bar = annual median
TP mg/L
YEAR

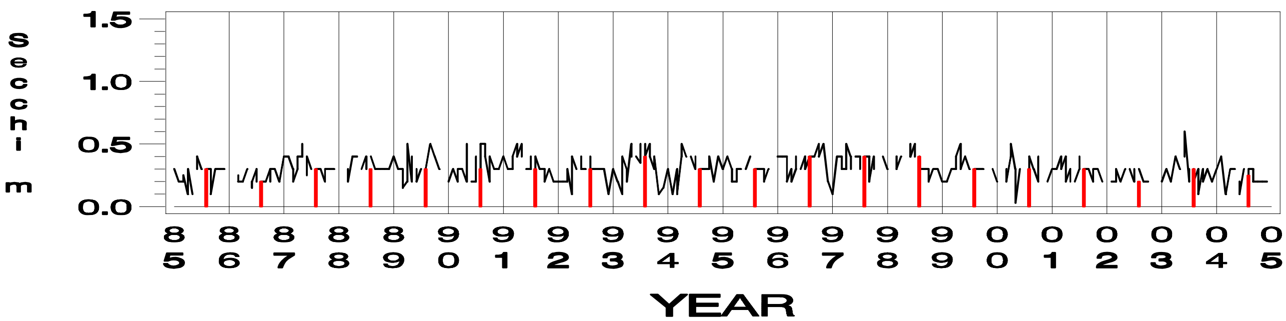

Chlorophyll a at TF1.5 (Nottingham), 1985-2004, layer=SAP
red bar = annual median
CHLA ug/L
YEAR


Total Susp. Solids at TF1.5 (Nottingham), 1985-2004, layer=SAP
red bar = annual median
TSS mg/L
YEAR

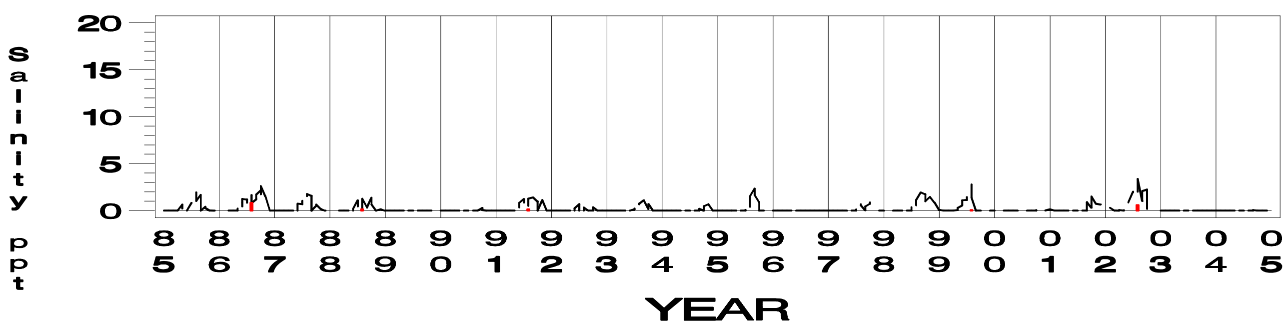
Dissolved Oxygen at TF1.5 (Nottingham), 1985—2004, layer=BDO
red bar = annual median



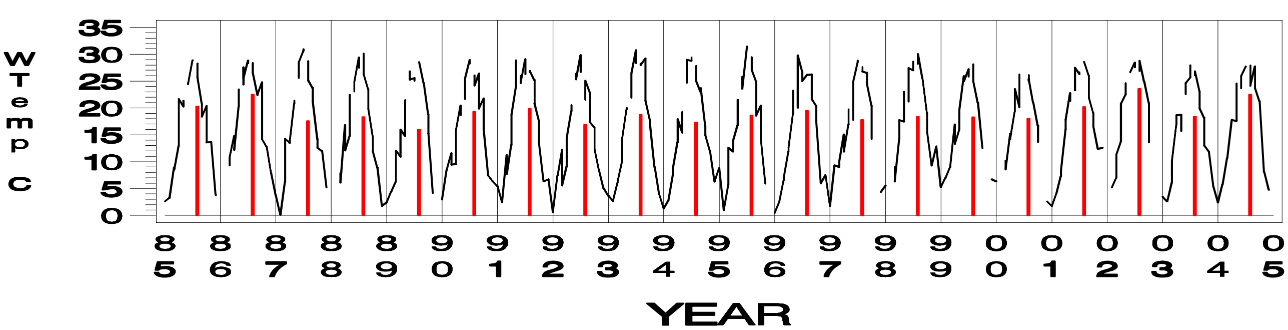
Secchi Depth at TF1.5 (Nottingham), 1985—2004, layer=S
red bar = annual median

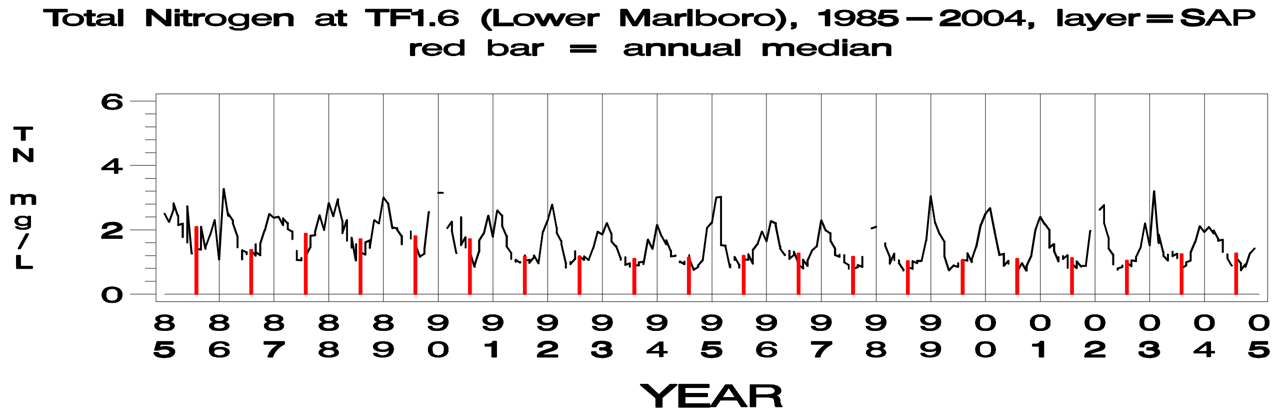


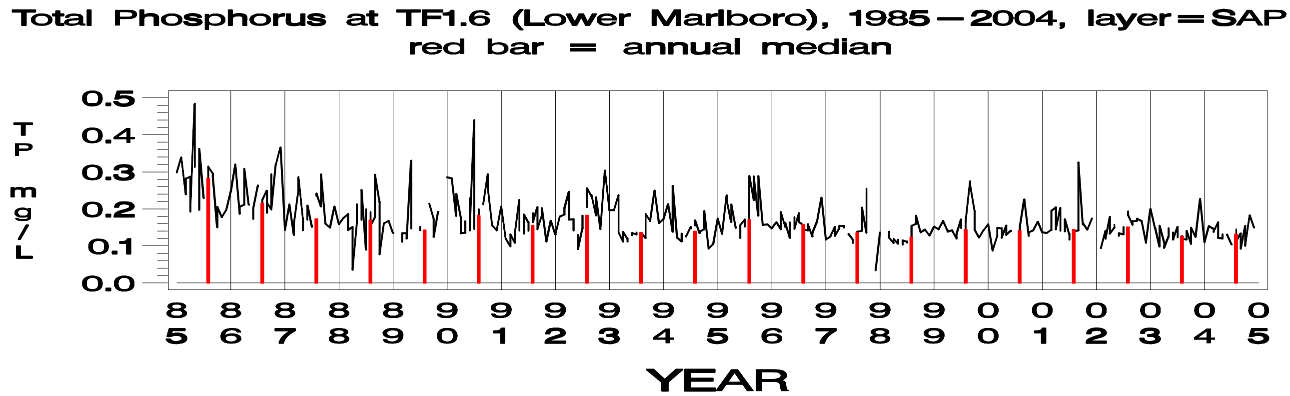
Salinity at TF1.5 (Nottingham), 1985—2004, layer=SAP
red bar = annual median

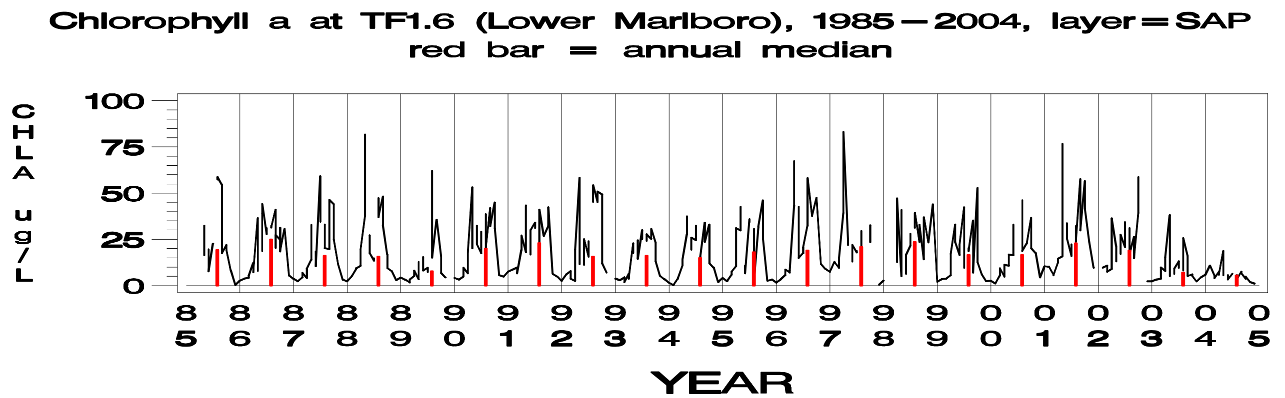


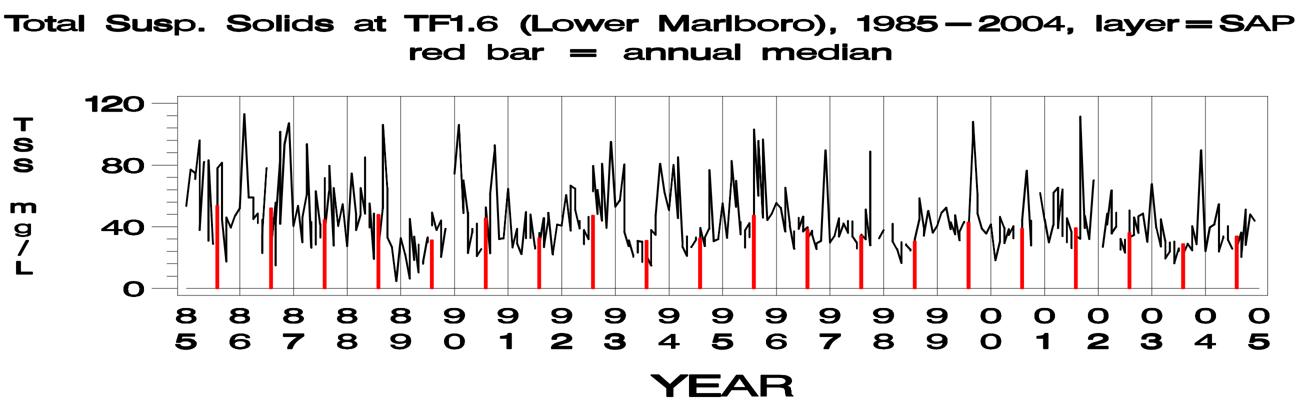
Water Temperature at TF1.5 (Nottingham), 1985—2004, layer=SAP
red bar = annual median



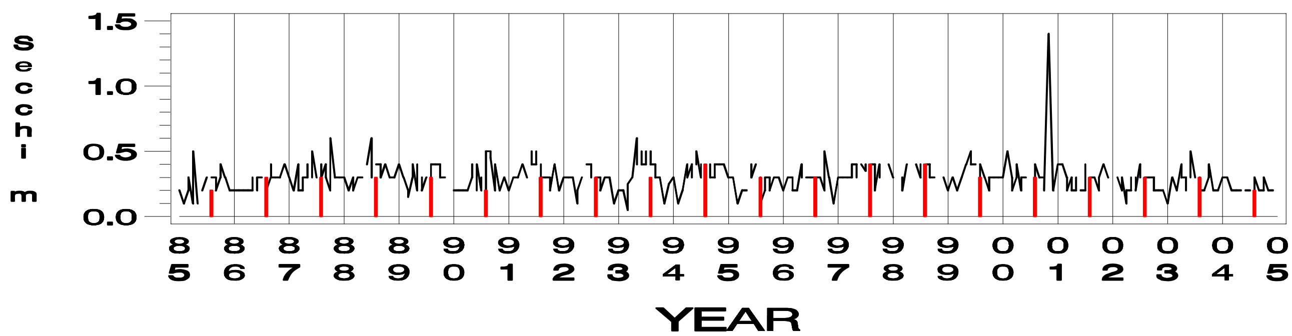

Total Nitrogen at TF1.6 (Lower Marlboro), 1985—2004, layer=SAP
red bar = annual median
T N mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR


Total Phosphorus at TF1.6 (Lower Marlboro), 1985—2004, layer=SAP
red bar = annual median
T P mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR

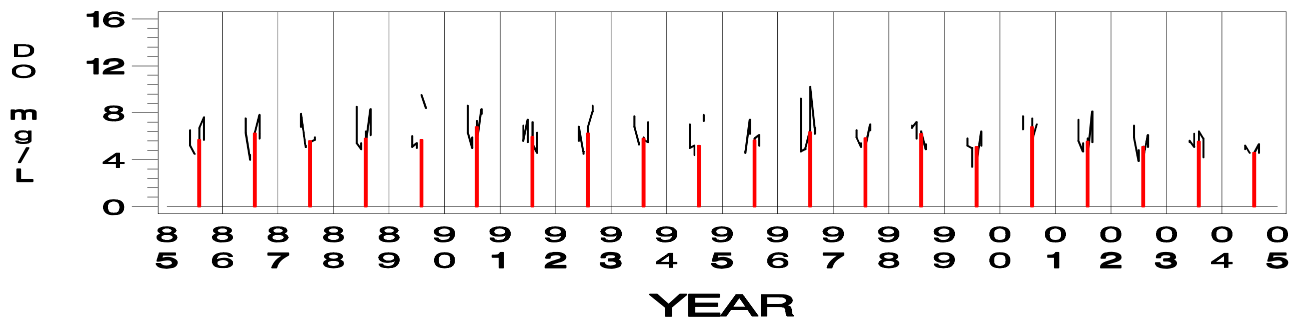

Chlorophyll a at TF1.6 (Lower Marlboro), 1985—2004, layer=SAP
red bar = annual median
CHLA ug/L
0
25
50
75
100
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR


Total Susp. Solids at TF1.6 (Lower Marlboro), 1985—2004, layer=SAP
red bar = annual median
TSS mg/L
0
40
80
120
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR

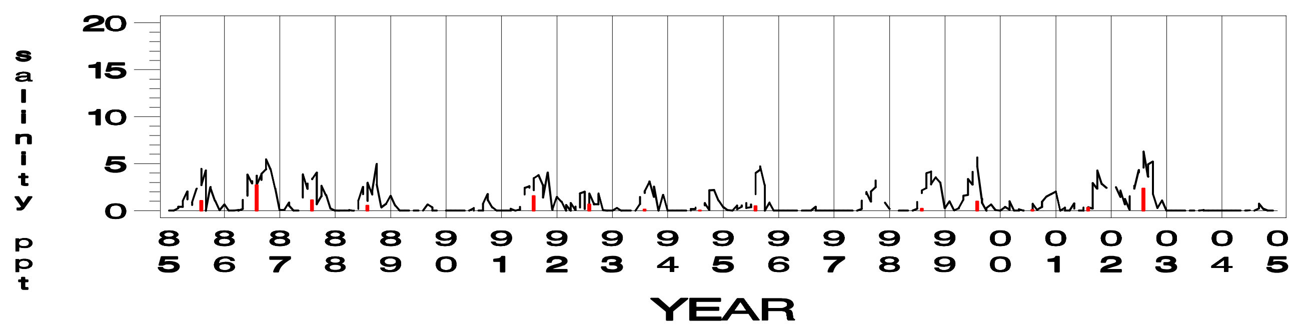
Secchi Depth at TF1.6 (Lower Marlboro), 1985—2004, layer=S
red bar = annual median



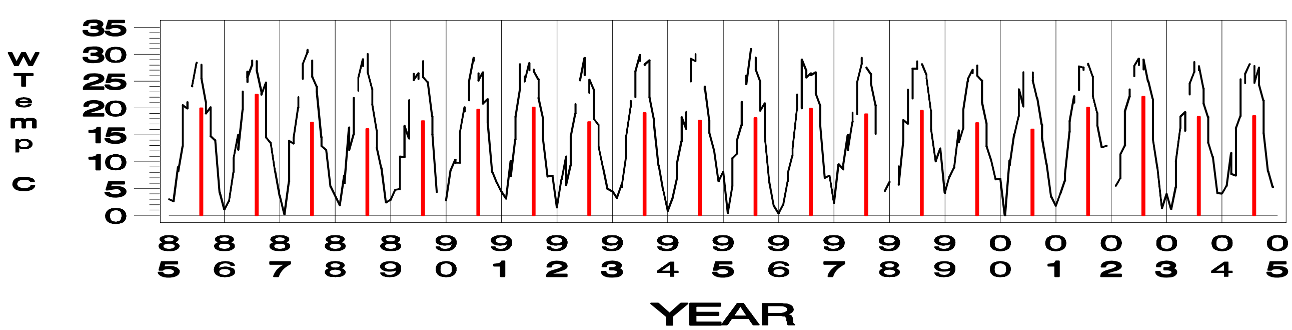
Dissolved Oxygen at TF1.6 (Lower Marlboro), 1985—2004, layer=BDO
red bar = annual median



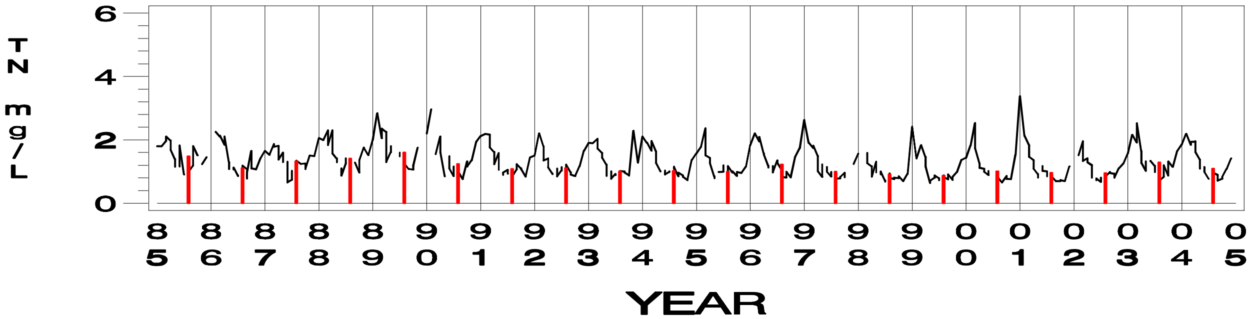
Salinity at TF1.6 (Lower Marlboro), 1985—2004, layer=SAP
red bar = annual median



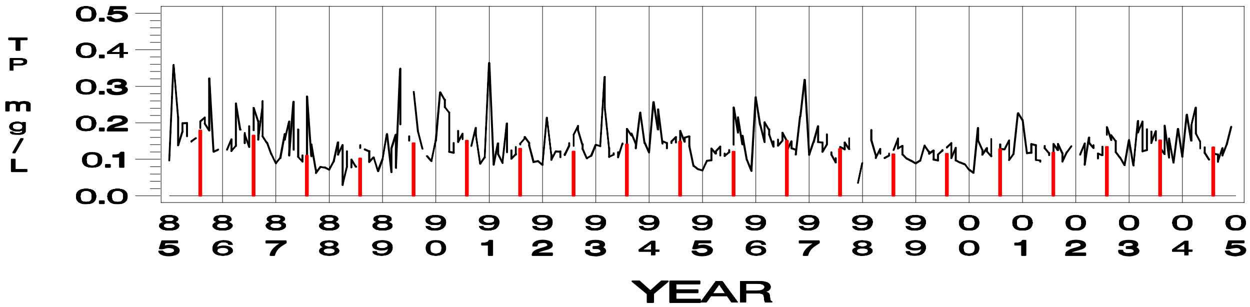
Water Temperature at TF1.6 (Lower Marlboro), 1985—2004, layer=SAP
red bar = annual median



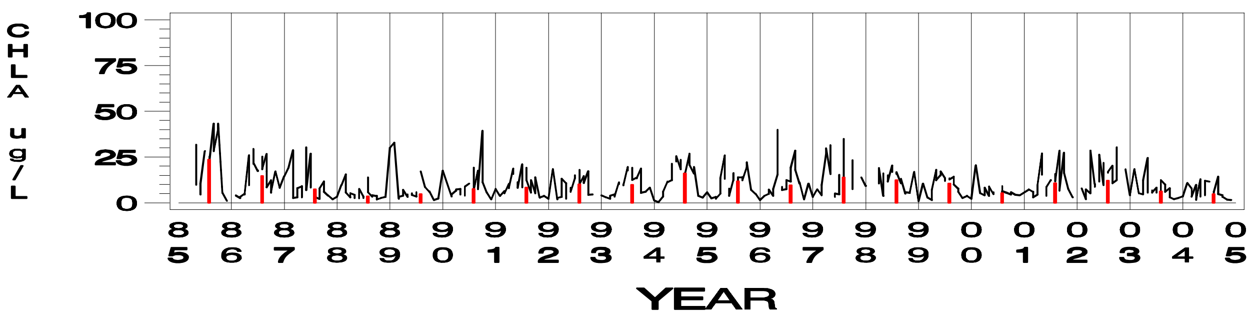
Total Nitrogen at TF1.7 (Above Benedict), 1985-2004, layer=SAP
red bar = annual median



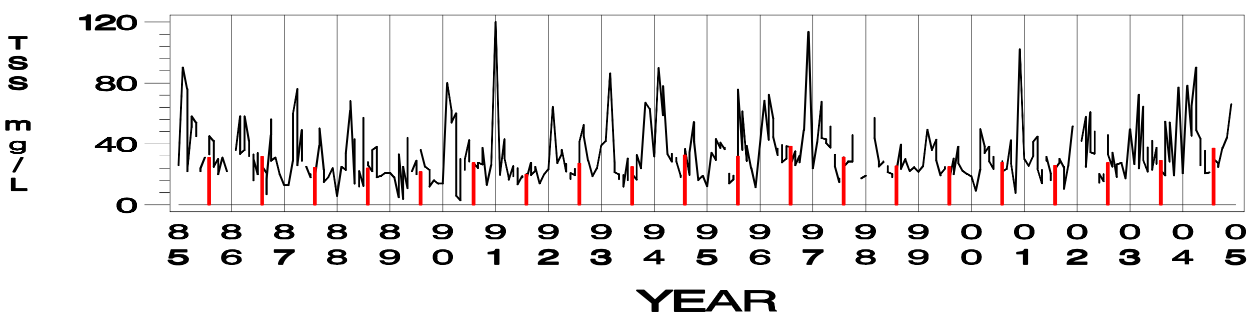
Total Phosphorus at TF1.7 (Above Benedict), 1985-2004, layer=SAP
red bar = annual median



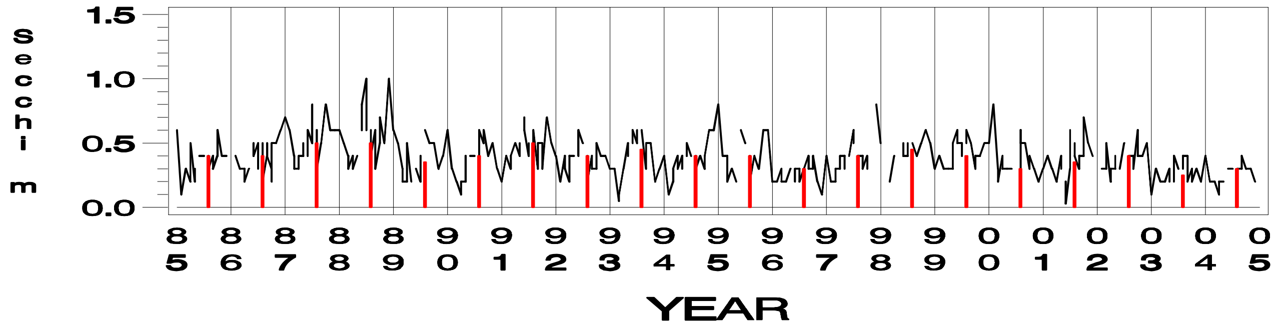
Chlorophyll a at TF1.7 (Above Benedict), 1985-2004, layer=SAP
red bar = annual median



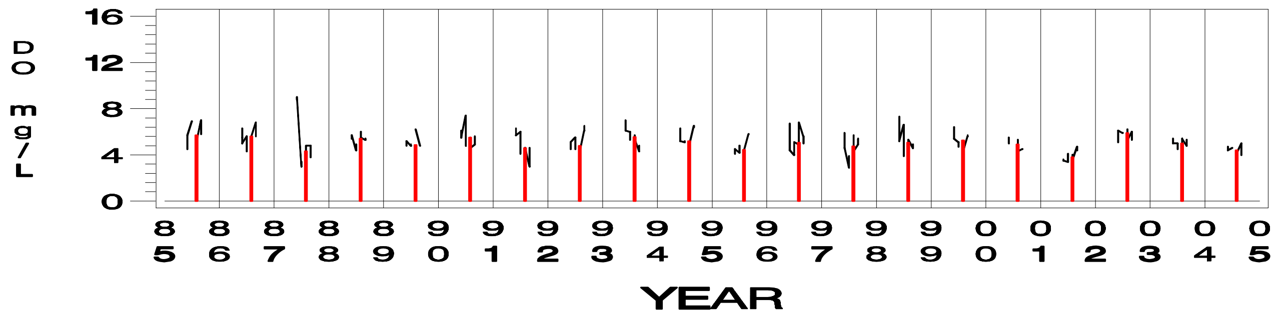
Total Susp. Solids at TF1.7 (Above Benedict), 1985-2004, layer=SAP
red bar = annual median



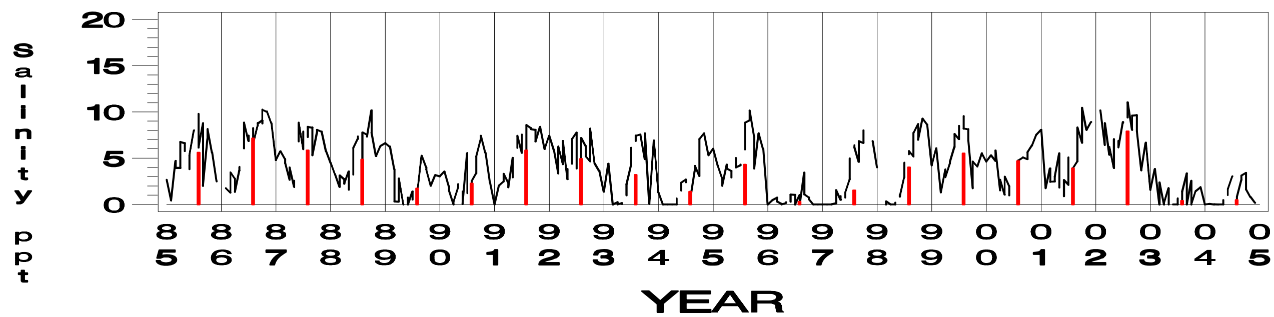
Secchi Depth at TF1.7 (Above Benedict), 1985—2004, layer=S
red bar = annual median



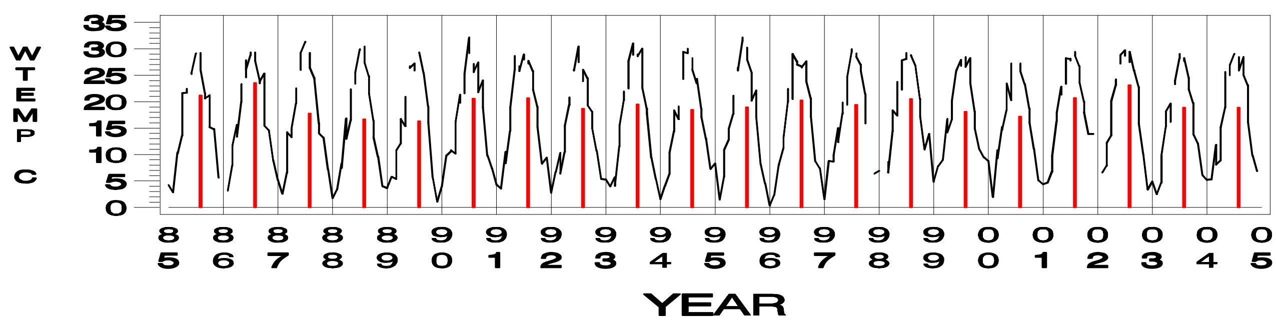
Dissolved Oxygen at TF1.7 (Above Benedict), 1985—2004, layer=BDO
red bar = annual median



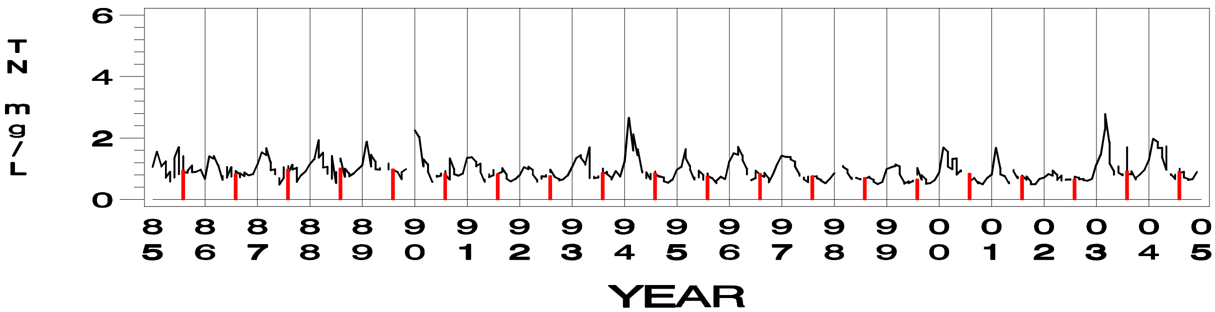
Salinity at TF1.7 (Above Benedict), 1985—2004, layer=SAP
red bar = annual median



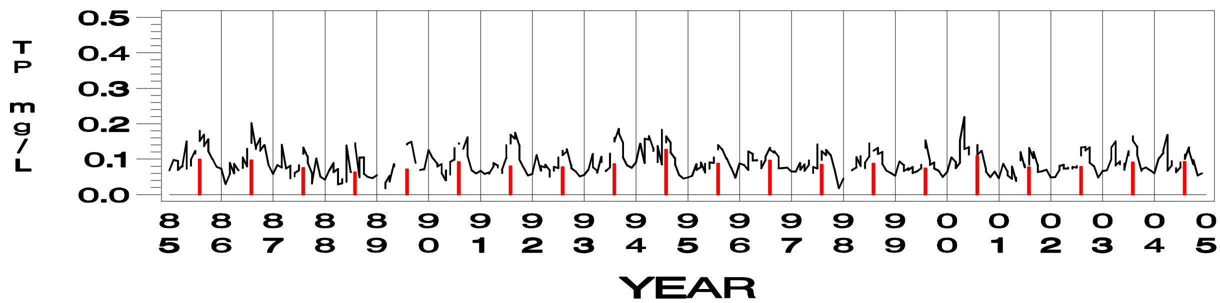
Water Temperature at TF1.7 (Above Benedict), 1985—2004, layer=SAP
red bar = annual median



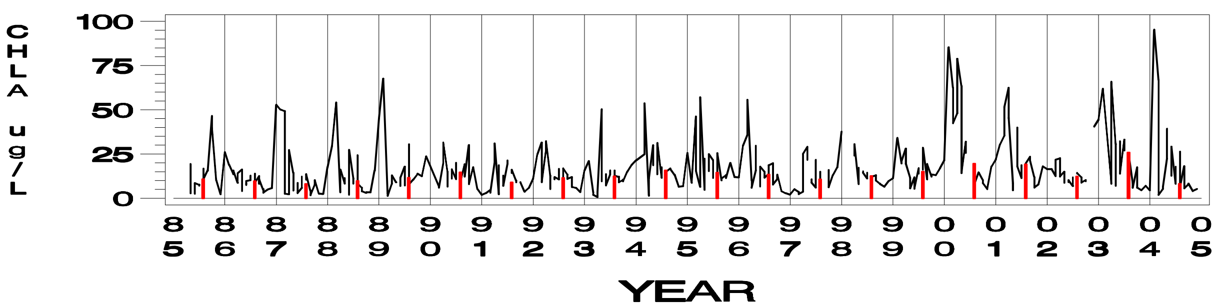
Total Nitrogen at RET1.1 (Below Benedict), 1985-2004, layer=SAP
red bar = annual median



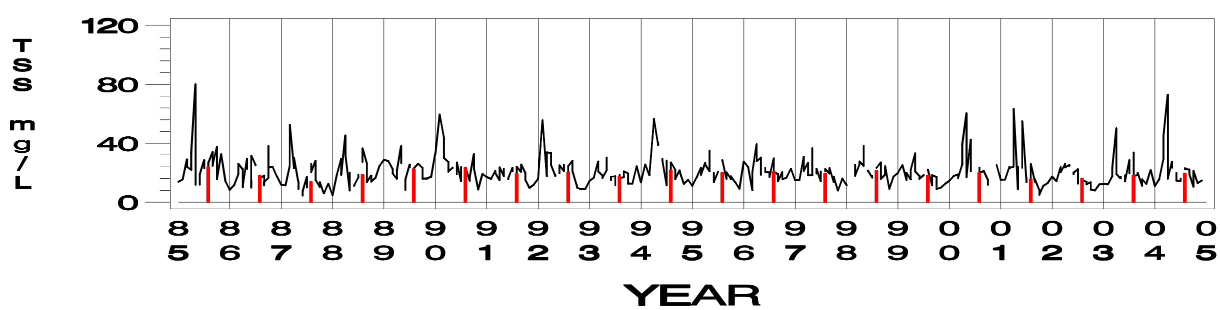
Total Phosphorus at RET1.1 (Below Benedict), 1985-2004, layer=SAP
red bar = annual median



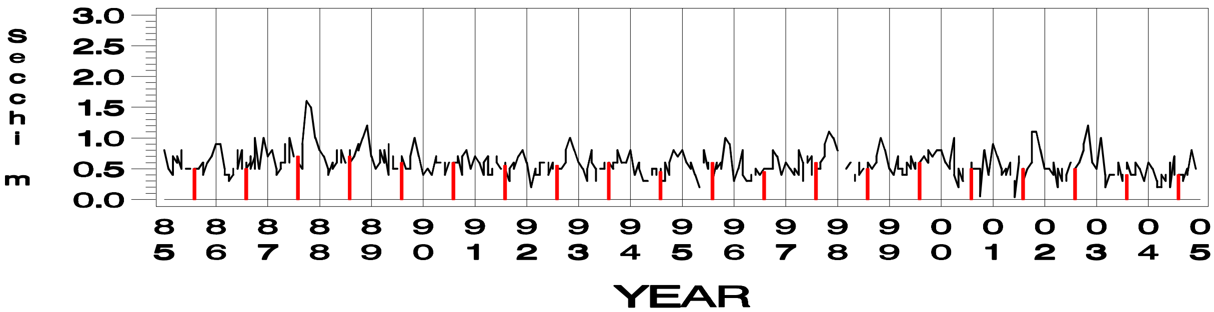
Chlorophyll a at RET1.1 (Below Benedict), 1985-2004, layer=SAP
red bar = annual median



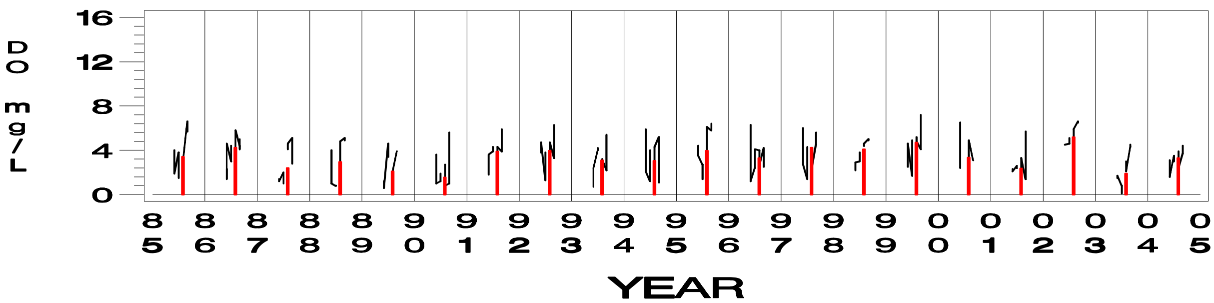
Total Susp. Solids at RET1.1 (Below Benedict), 1985-2004, layer=SAP
red bar = annual median



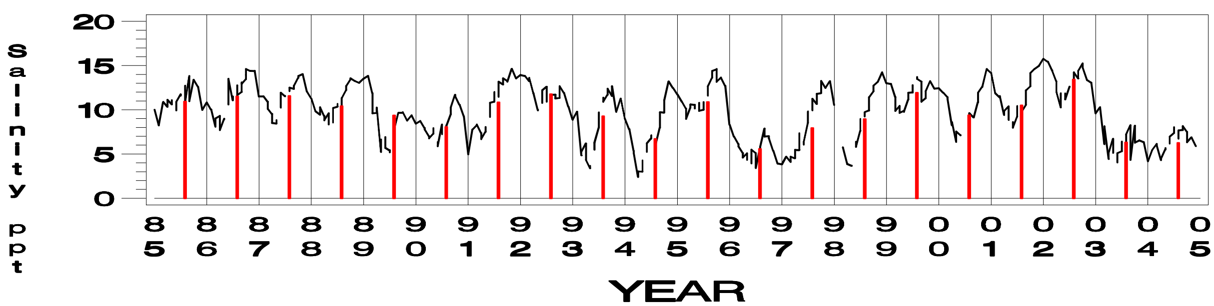
Secchi Depth at RET1.1 (Below Benedict), 1985—2004, layer=S
red bar = annual median



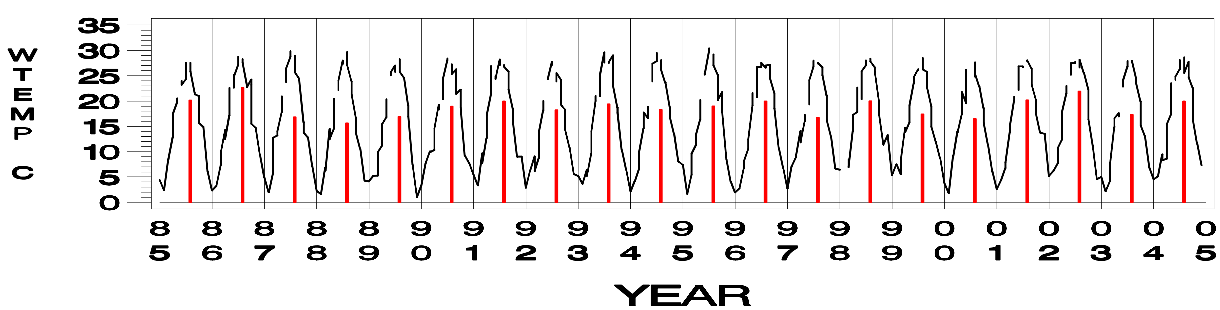
Dissolved Oxygen at RET1.1 (Below Benedict), 1985—2004, layer=BDO
red bar = annual median

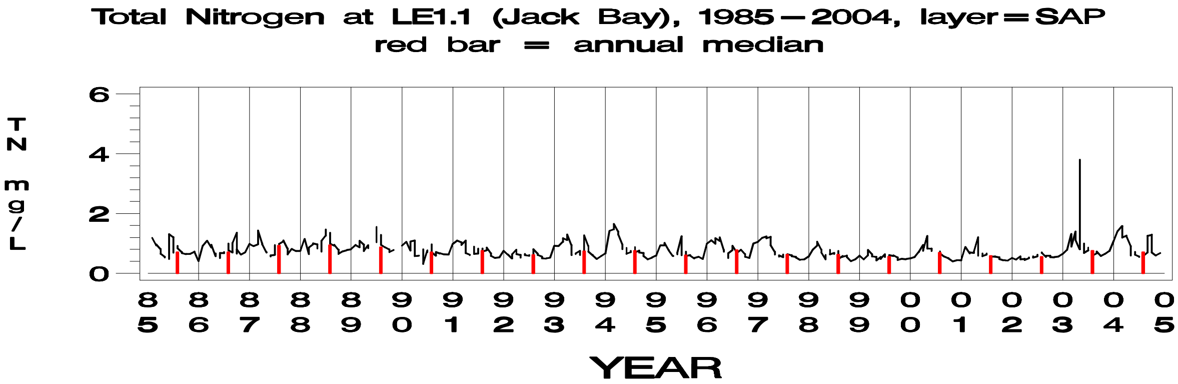


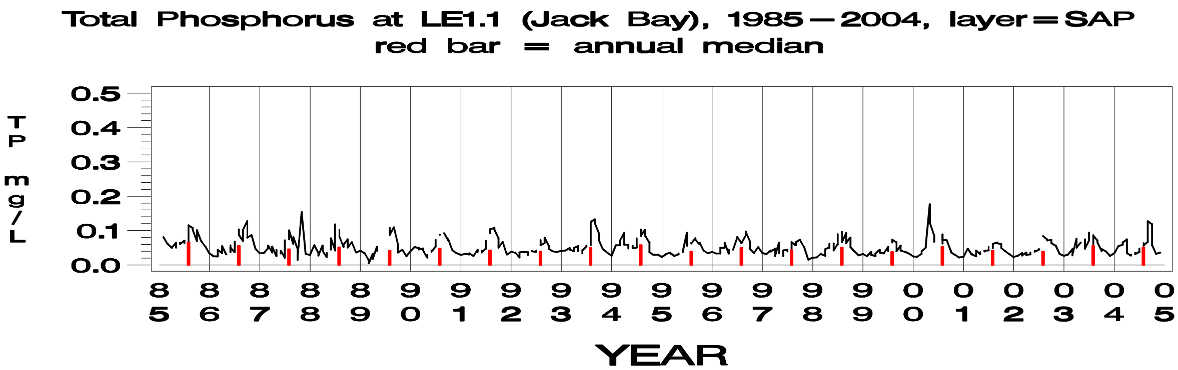
Salinity at RET1.1 (Below Benedict), 1985—2004, layer=SAP
red bar = annual median

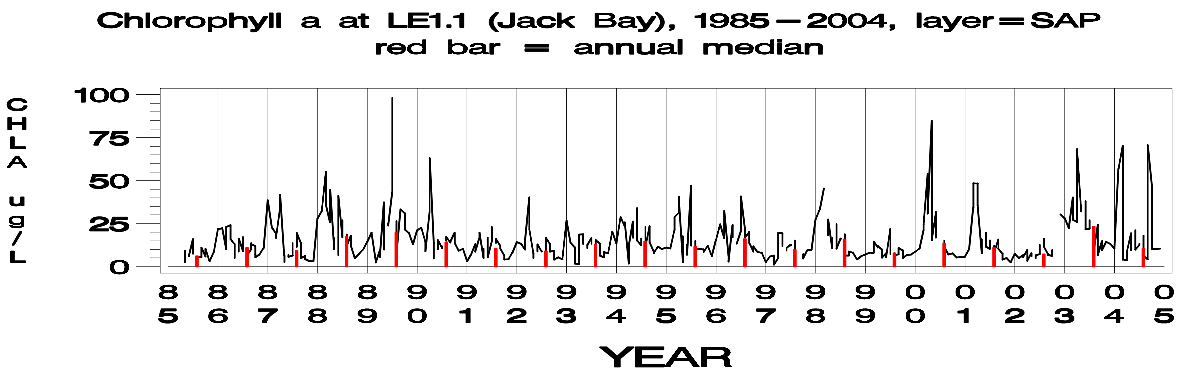


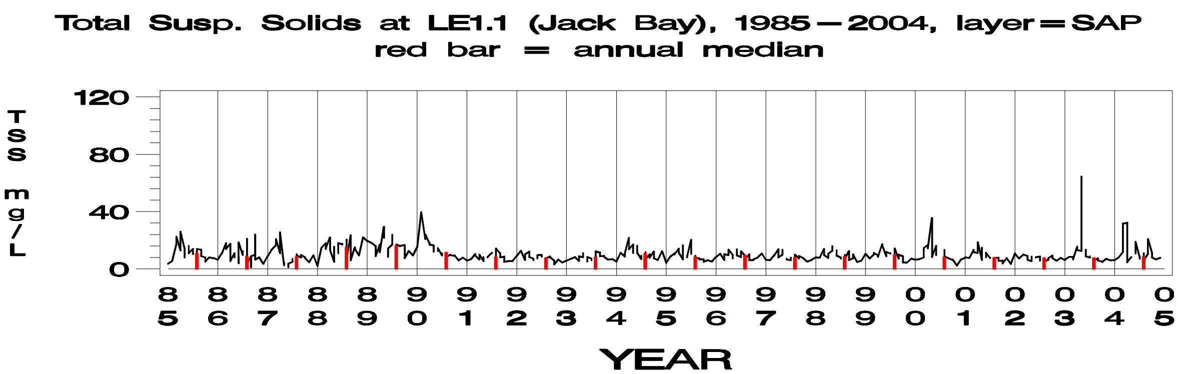
Water Temperature at RET1.1 (Below Benedict), 1985—2004, layer=SAP
red bar = annual median

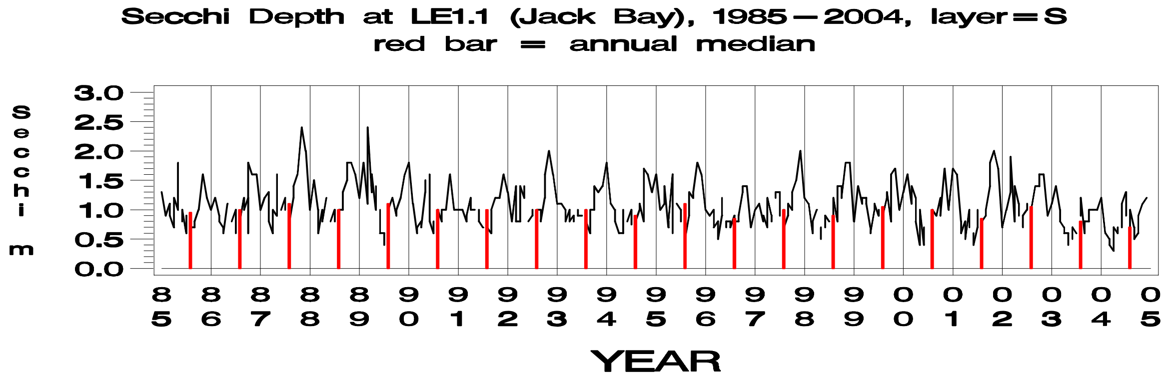


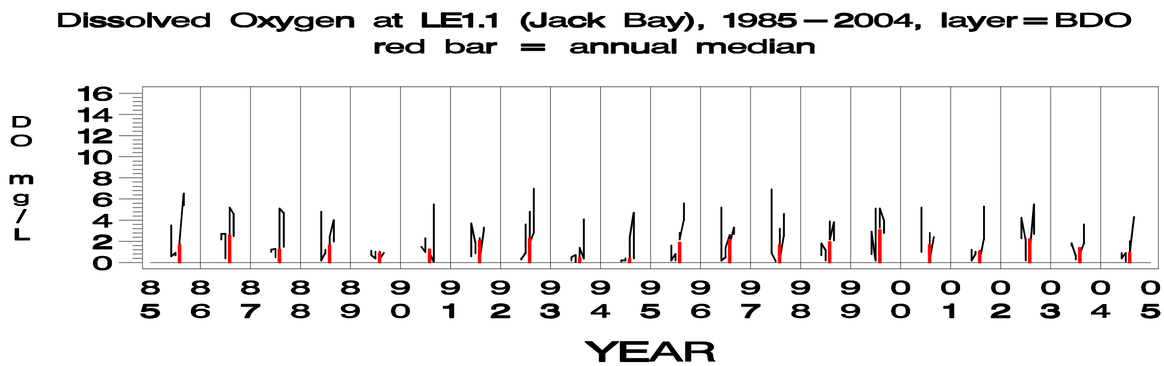

Total Nitrogen at LE1.1 (Jack Bay), 1985—2004, layer=SAP
red bar = annual median
TN mg/L
YEAR

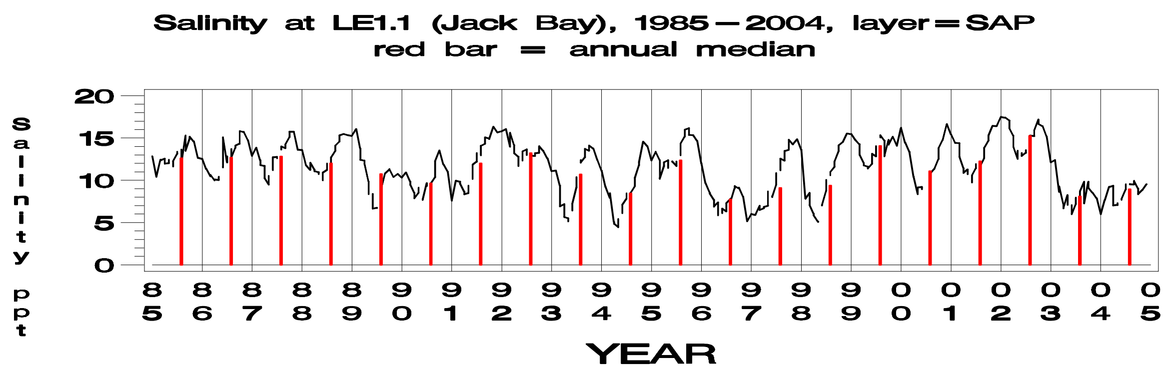

Total Phosphorus at LE1.1 (Jack Bay), 1985—2004, layer=SAP
red bar = annual median
TP mg/L
YEAR

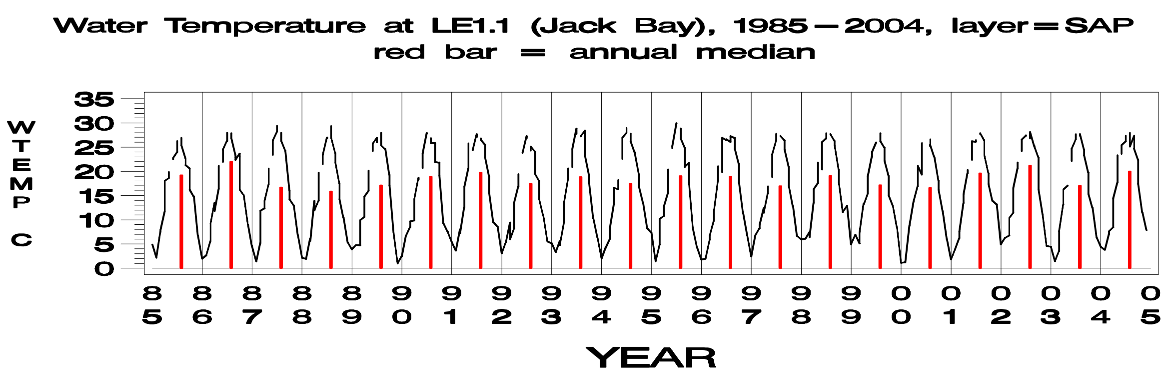

Chlorophyll a at LE1.1 (Jack Bay), 1985—2004, layer=SAP
red bar = annual median
CHLA ug/L
YEAR


Total Susp. Solids at LE1.1 (Jack Bay), 1985—2004, layer=SAP
red bar = annual median
TSS mg/L
YEAR

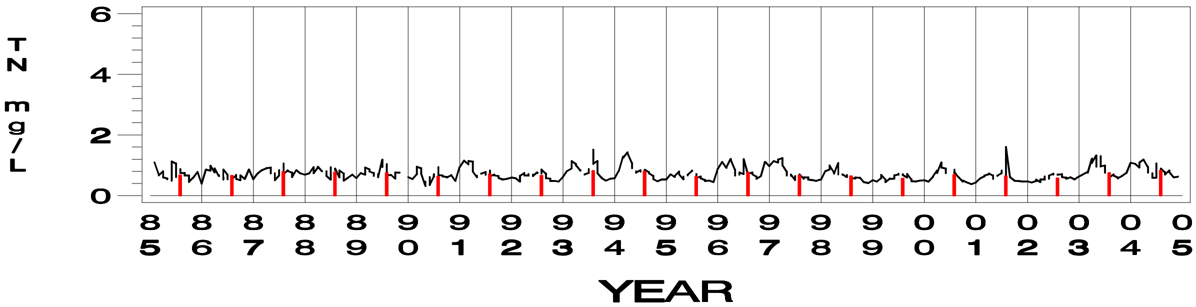

Secchi Depth at LE1.1 (Jack Bay), 1985 — 2004, layer = S
red bar = annual median
Secchi m
YEAR


Dissolved Oxygen at LE1.1 (Jack Bay), 1985 — 2004, layer = BDO
red bar = annual median
DO mg/L
YEAR

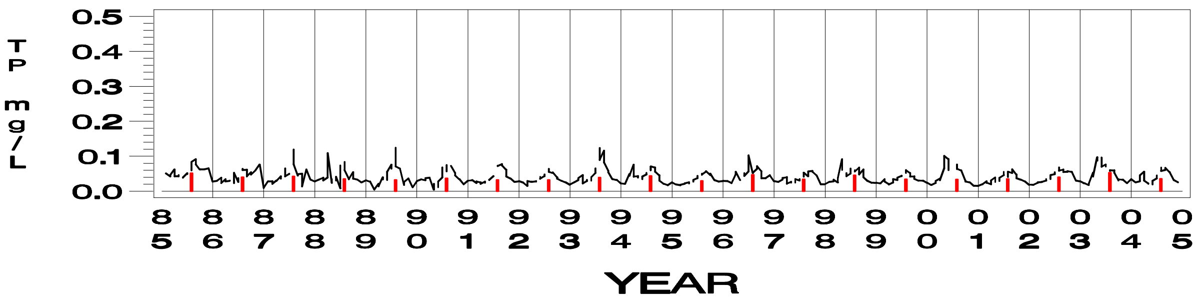

Salinity at LE1.1 (Jack Bay), 1985 — 2004, layer = SAP
red bar = annual median
Salinity ppt
YEAR


Water Temperature at LE1.1 (Jack Bay), 1985 — 2004, layer = SAP
red bar = annual median
WTEMP C
YEAR

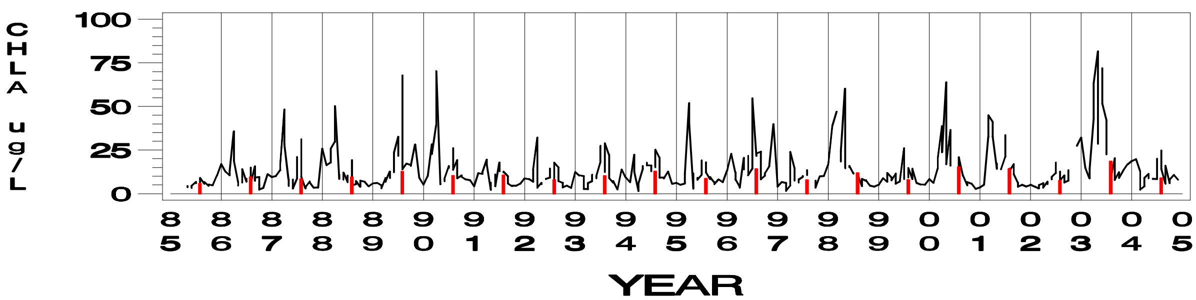
Total Nitrogen at LE1.2 (St. Leonard), 1985—2004, layer=SAP
red bar = annual median



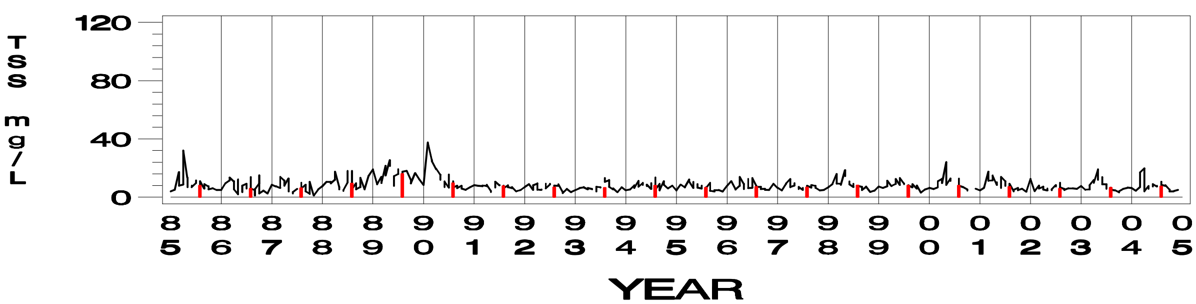
Total Phosphorus at LE1.2 (St. Leonard), 1985—2004, layer=SAP
red bar = annual median



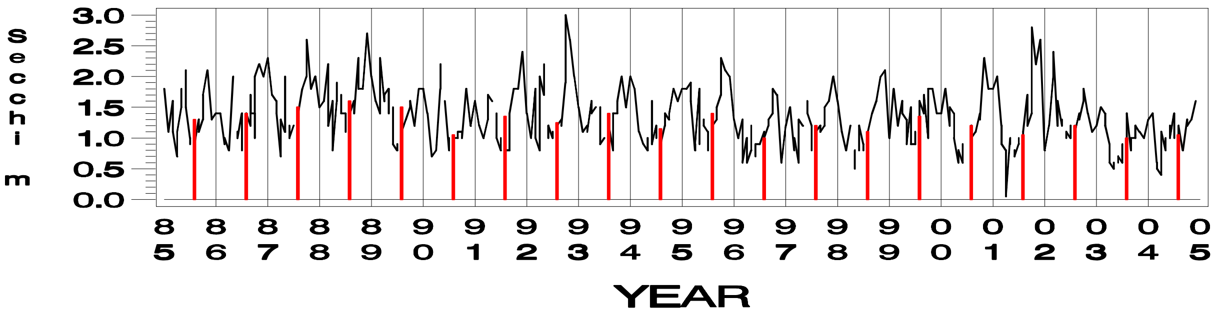
Chlorophyll a at LE1.2 (St. Leonard), 1985—2004, layer=SAP
red bar = annual median



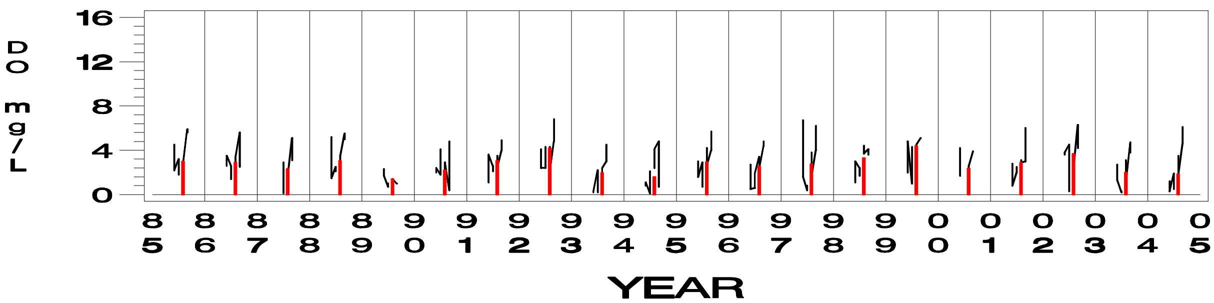
Total Susp. Solids at LE1.2 (St. Leonard), 1985—2004, layer=SAP
red bar = annual median



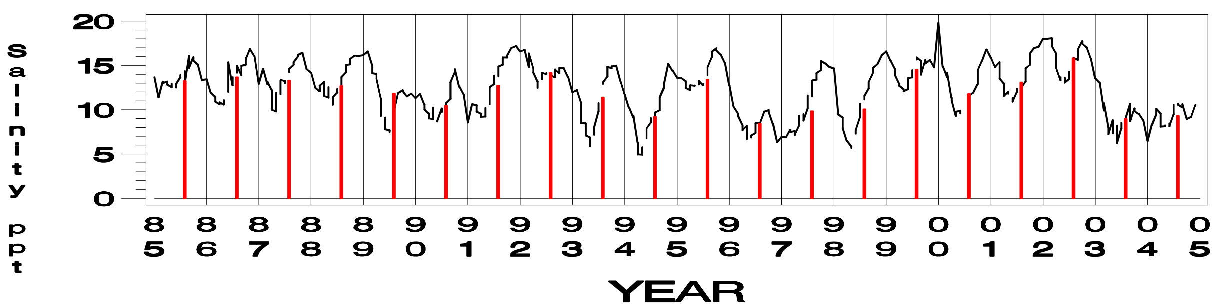
Secchi Depth at LE1.2 (St. Leonard), 1985—2004, layer=S
red bar = annual median



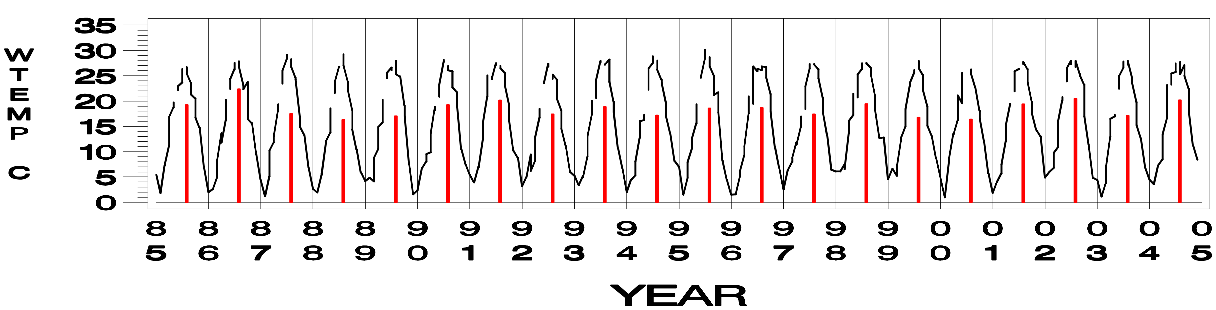
Dissolved Oxygen at LE1.2 (St. Leonard), 1985—2004, layer=BDO
red bar = annual median



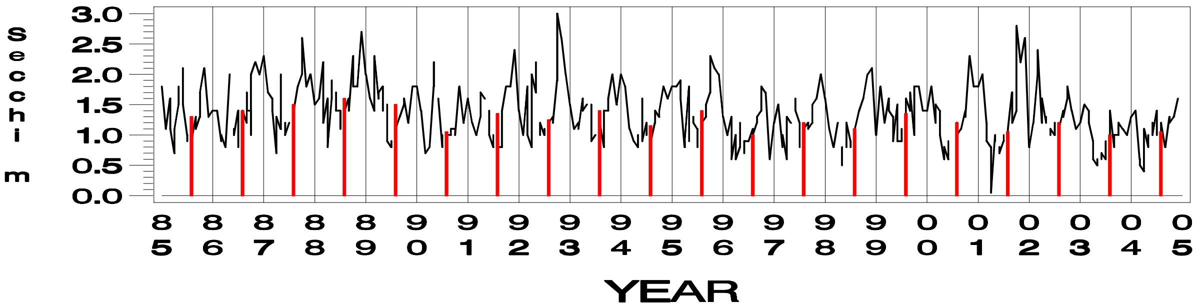
Salinity at LE1.2 (St. Leonard), 1985—2004, layer=SAP
red bar = annual median



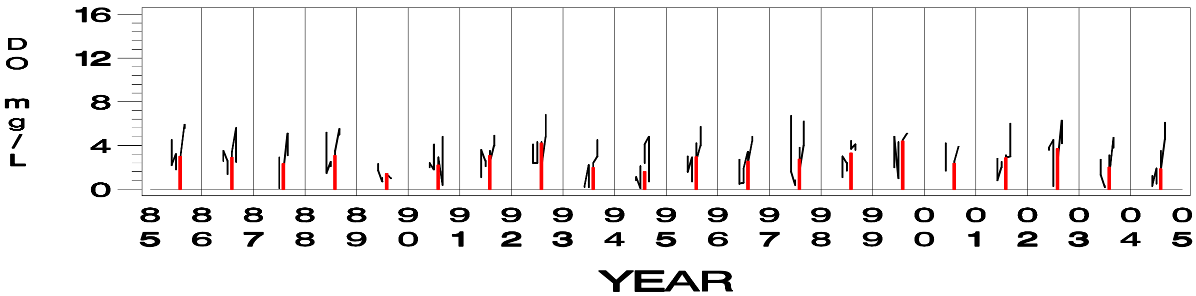
Water Temperature at LE1.2 (St. Leonard), 1985—2004, layer=SAP
red bar = annual median



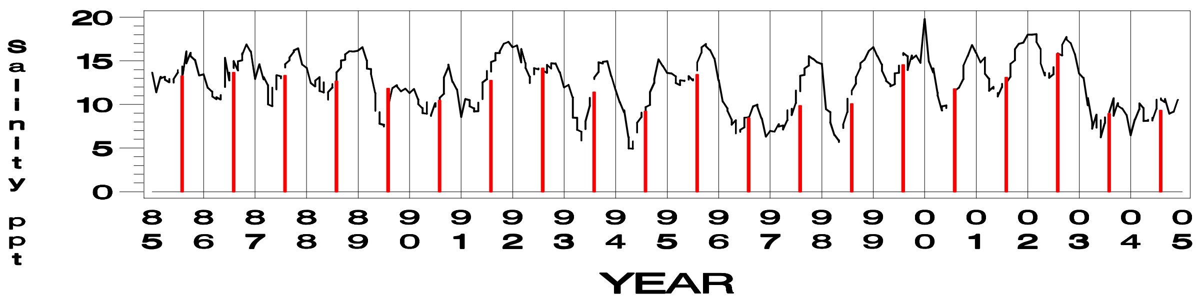
Secchi Depth at LE1.2 (St. Leonard), 1985–2004, layer=S
red bar = annual median



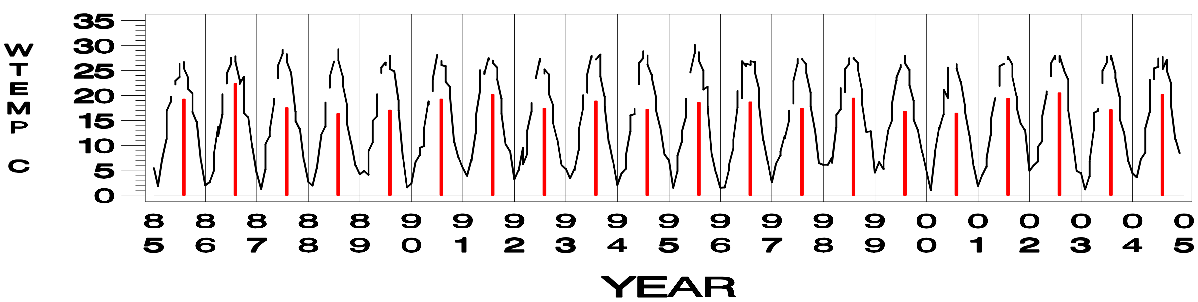
Dissolved Oxygen at LE1.2 (St. Leonard), 1985–2004, layer=BDO
red bar = annual median



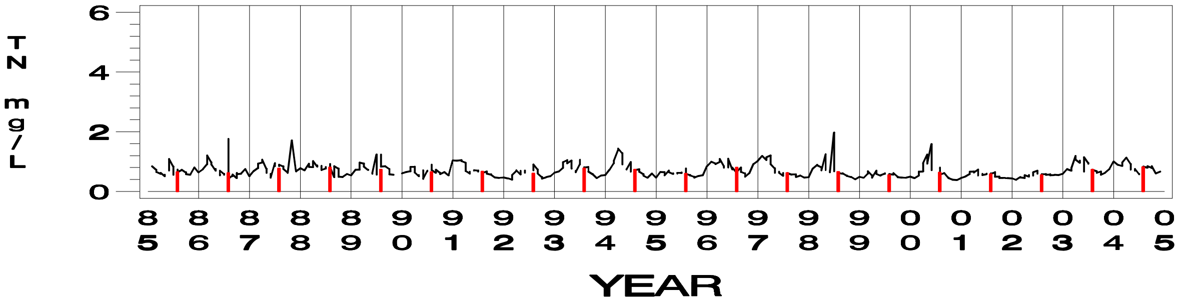
Salinity at LE1.2 (St. Leonard), 1985–2004, layer=SAP
red bar = annual median



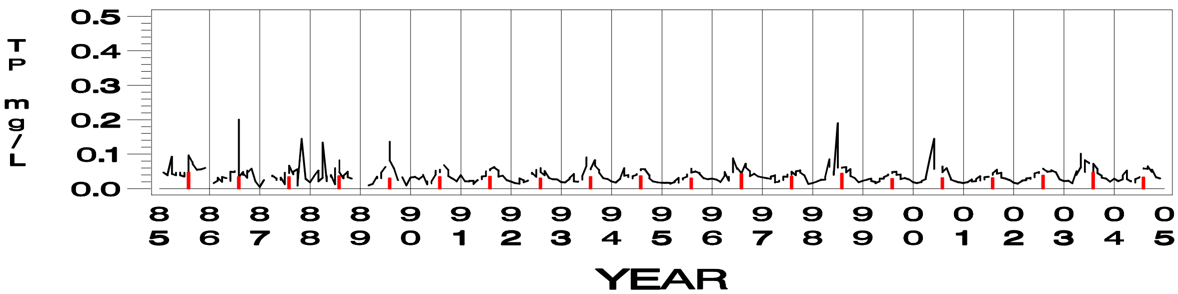
Water Temperature at LE1.2 (St. Leonard), 1985–2004, layer=SAP
red bar = annual median



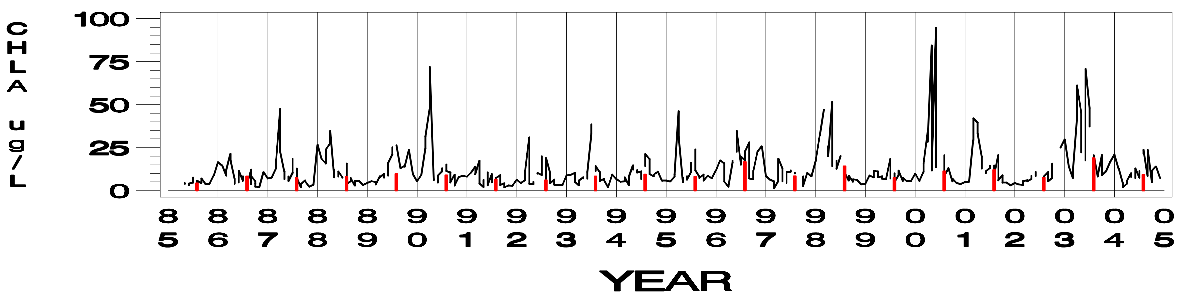
Total Nitrogen at LE1.3 (Above Pt. Patience), 1985—2004, layer=SAP
red bar = annual median



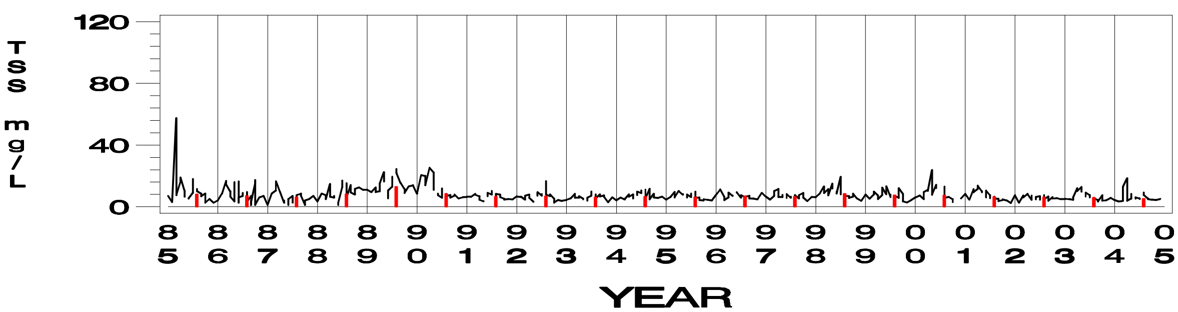
Total Phosphorus at LE1.3 (Above Pt. Patience), 1985—2004, layer=SAP
red bar = annual median



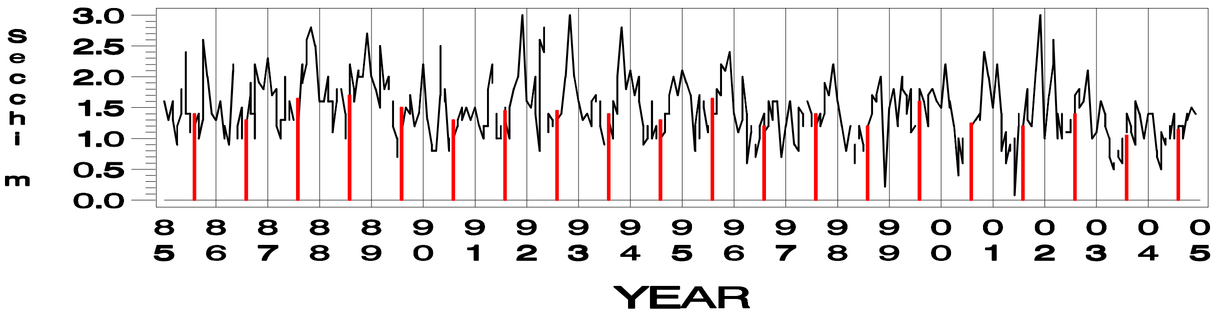
Chlorophyll a at LE1.3 (Above Pt. Patience), 1985—2004, layer=SAP
red bar = annual median



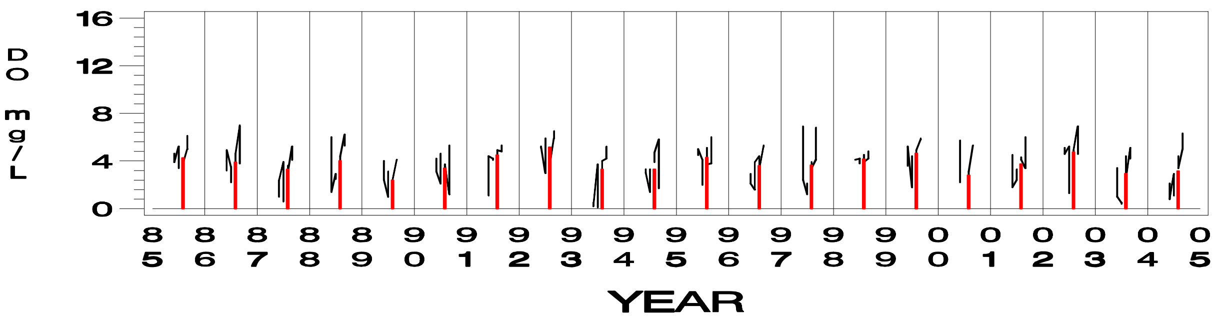
Total Susp. Solids at LE1.3 (Above Pt. Patience), 1985—2004, layer=SAP
red bar = annual median



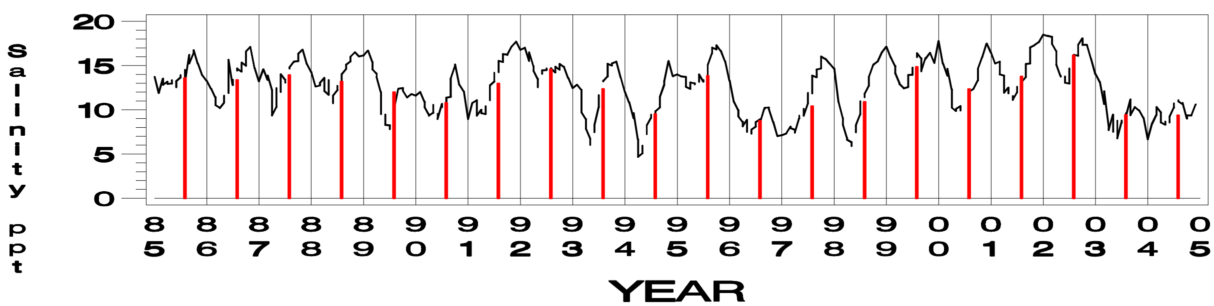
Secchi Depth at LE1.3 (Above Pt. Patience), 1985–2004, layer=S
red bar = annual median



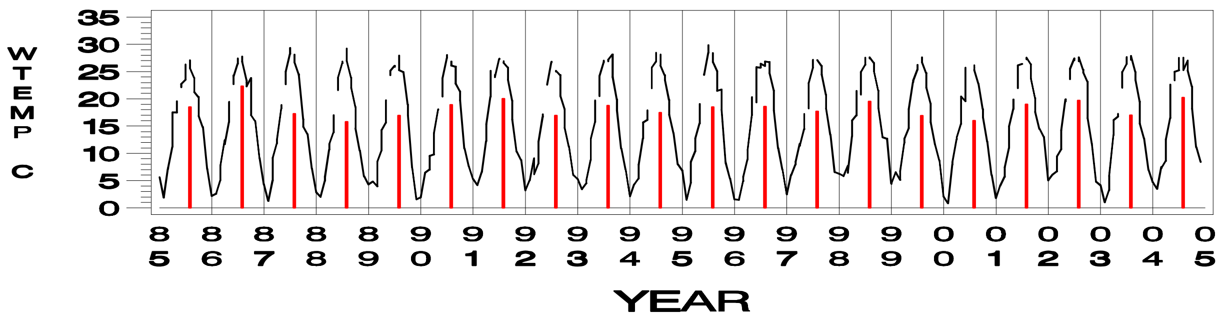
Dissolved Oxygen at LE1.3 (Above Pt. Patience), 1985–2004, layer=BDO
red bar = annual median



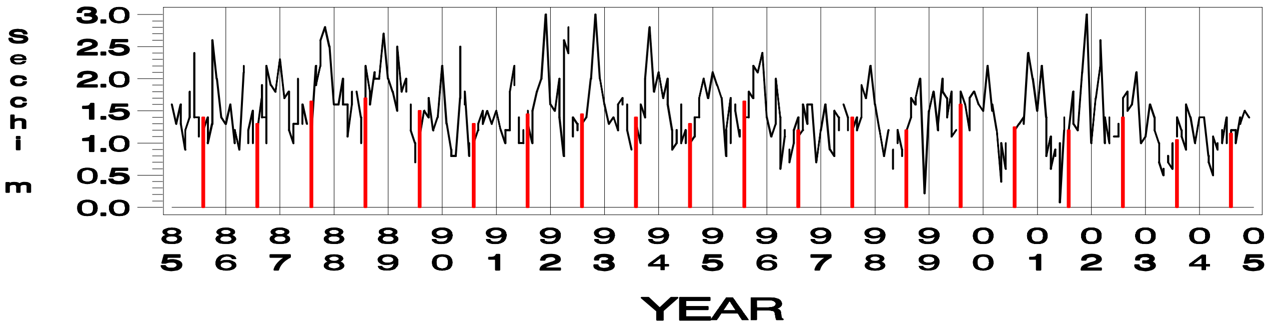
Salinity at LE1.3 (Above Pt. Patience), 1985–2004, layer=SAP
red bar = annual median



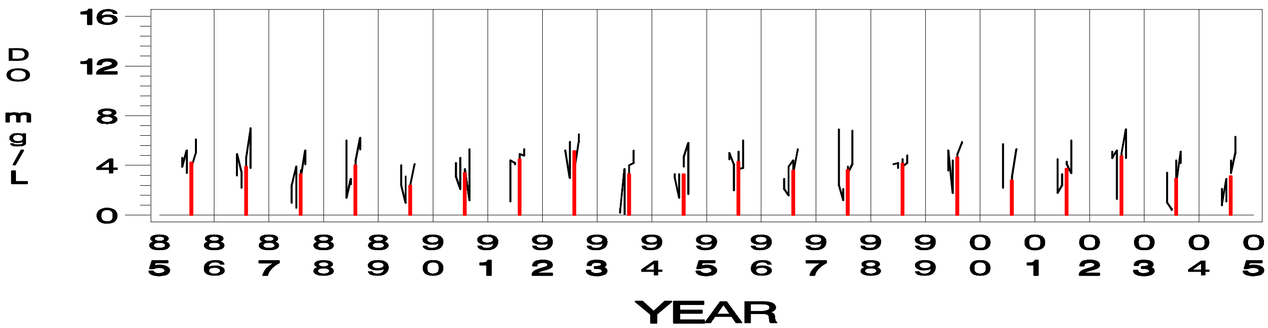
Water Temperature at LE1.3 (Above Pt. Patience), 1985–2004, layer=SAP
red bar = annual median



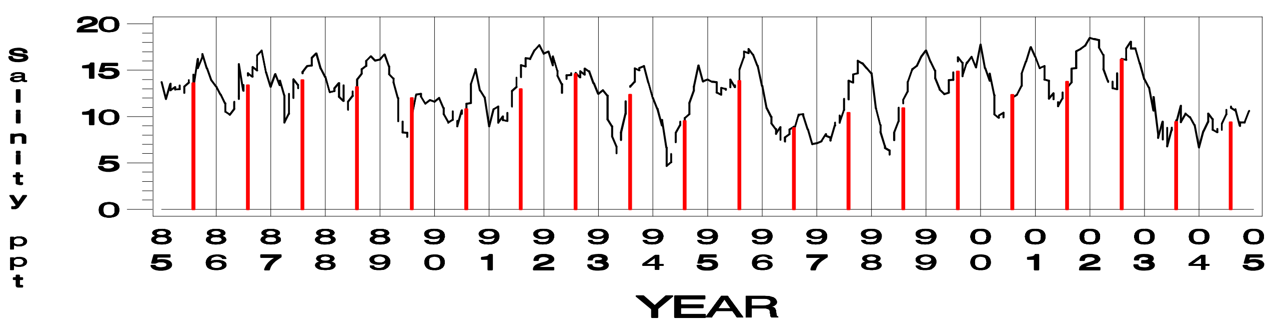
Secchi Depth at LE1.3 (Above Pt. Patience), 1985—2004, layer=S
red bar = annual median



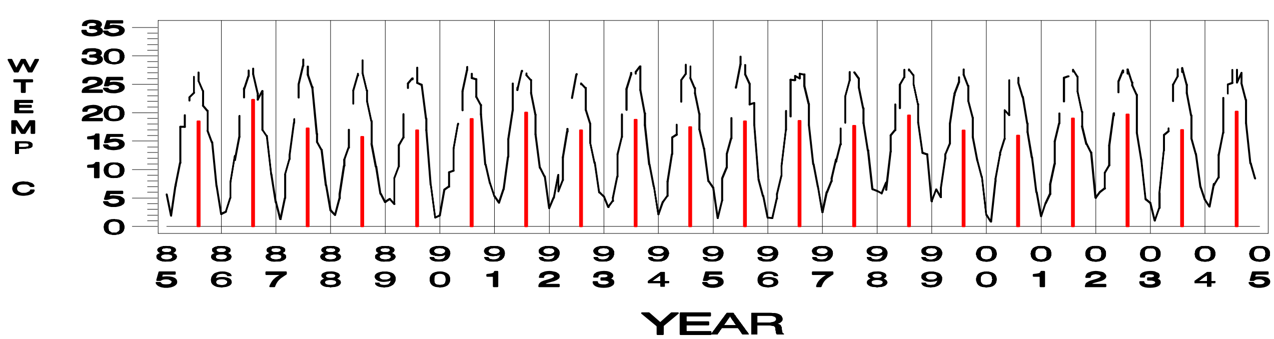
Dissolved Oxygen at LE1.3 (Above Pt. Patience), 1985—2004, layer=BDO
red bar = annual median



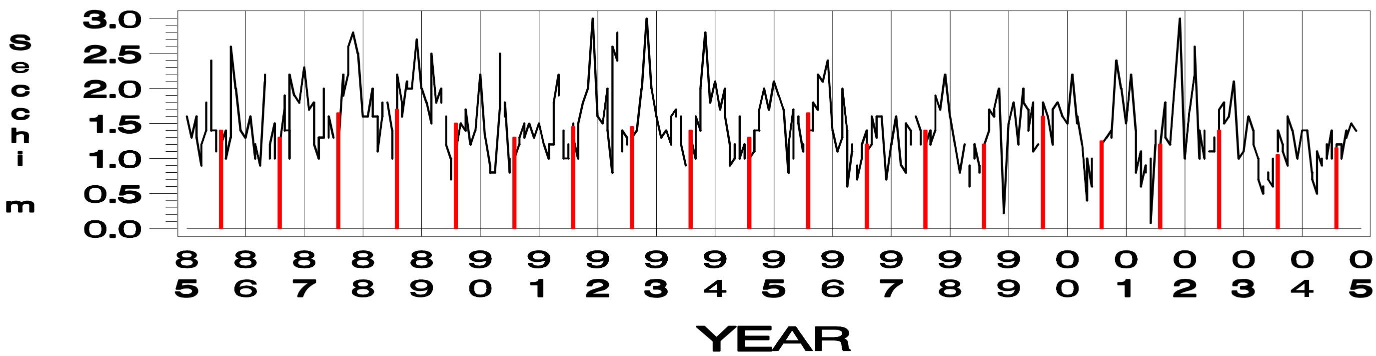
Salinity at LE1.3 (Above Pt. Patience), 1985—2004, layer=SAP
red bar = annual median



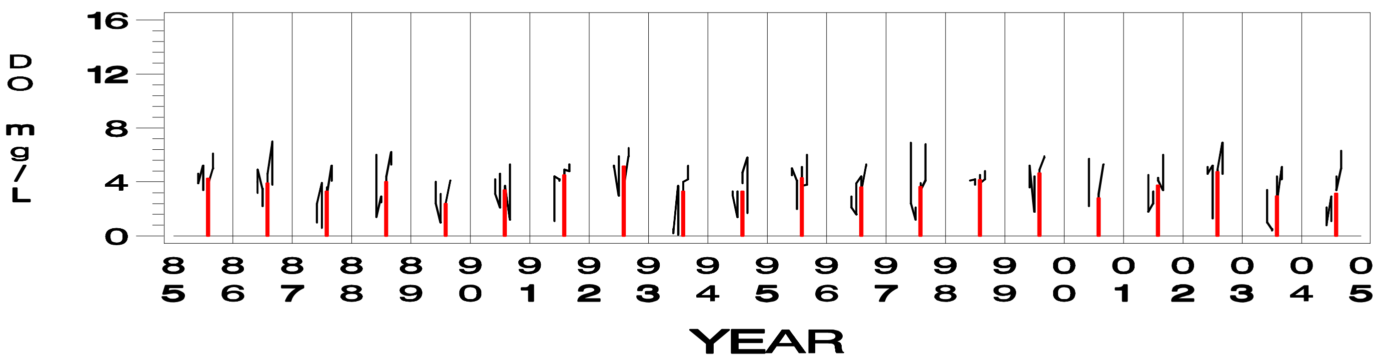
Water Temperature at LE1.3 (Above Pt. Patience), 1985—2004, layer=SAP
red bar = annual median



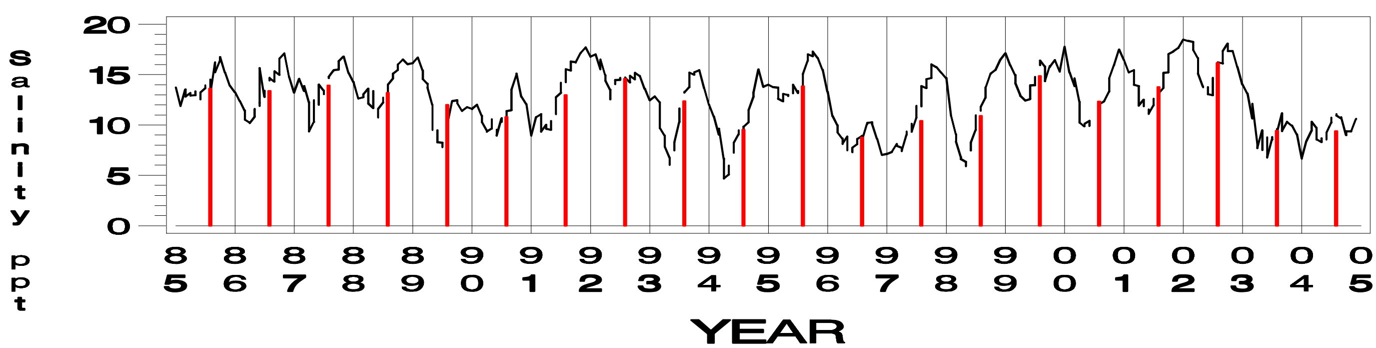
Secchi Depth at LE1.3 (Above Pt. Patience), 1985 — 2004, layer=S
red bar = annual median



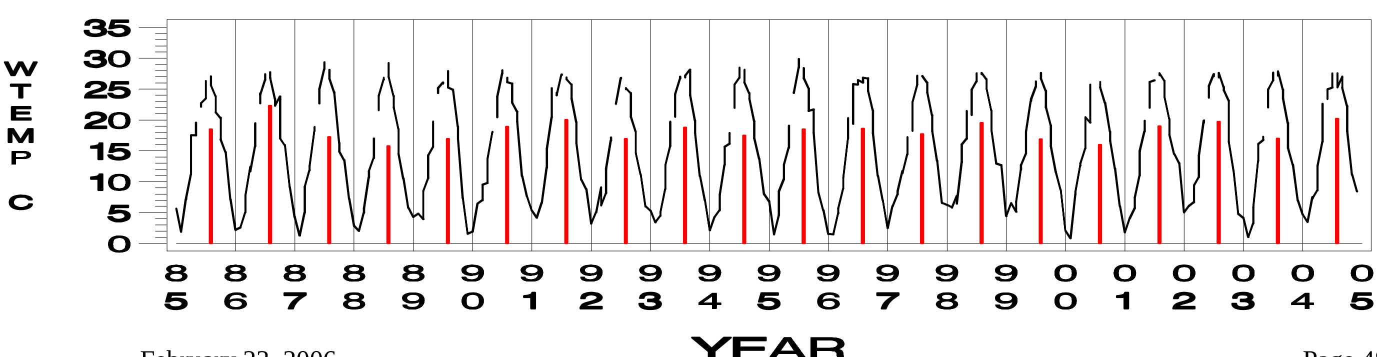
Dissolved Oxygen at LE1.3 (Above Pt. Patience), 1985 — 2004, layer=BDO
red bar = annual median

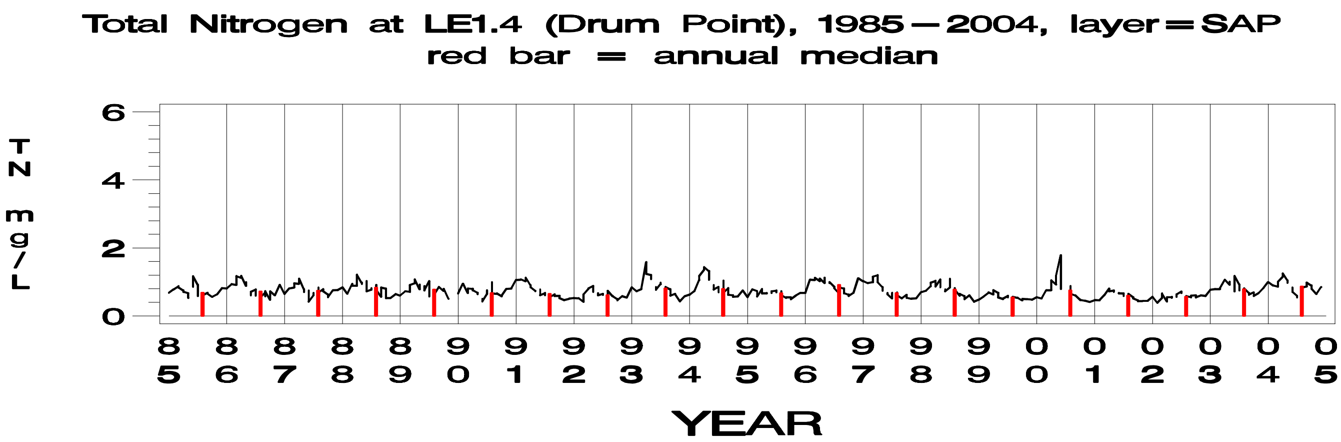


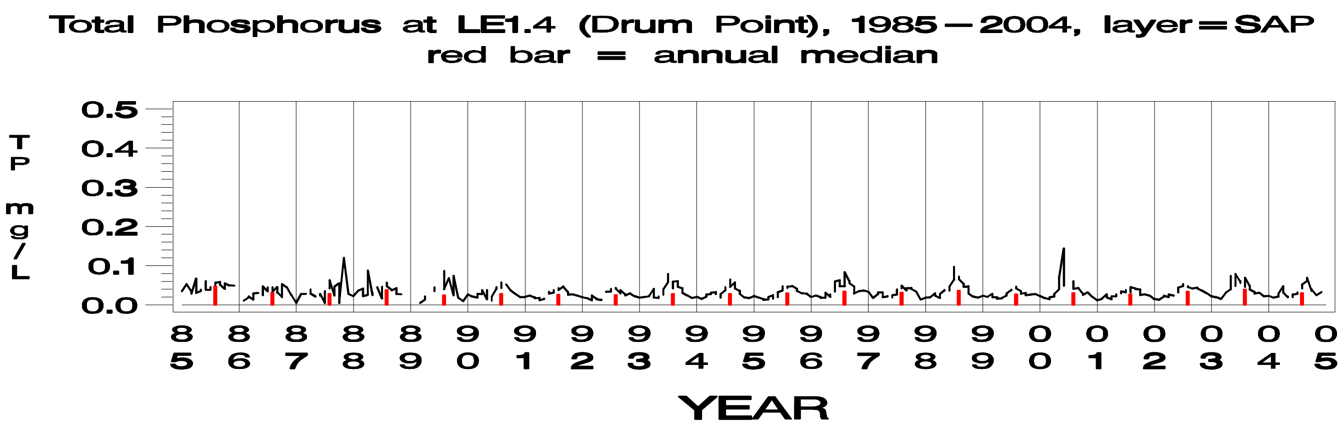
Salinity at LE1.3 (Above Pt. Patience), 1985 — 2004, layer=SAP
red bar = annual median

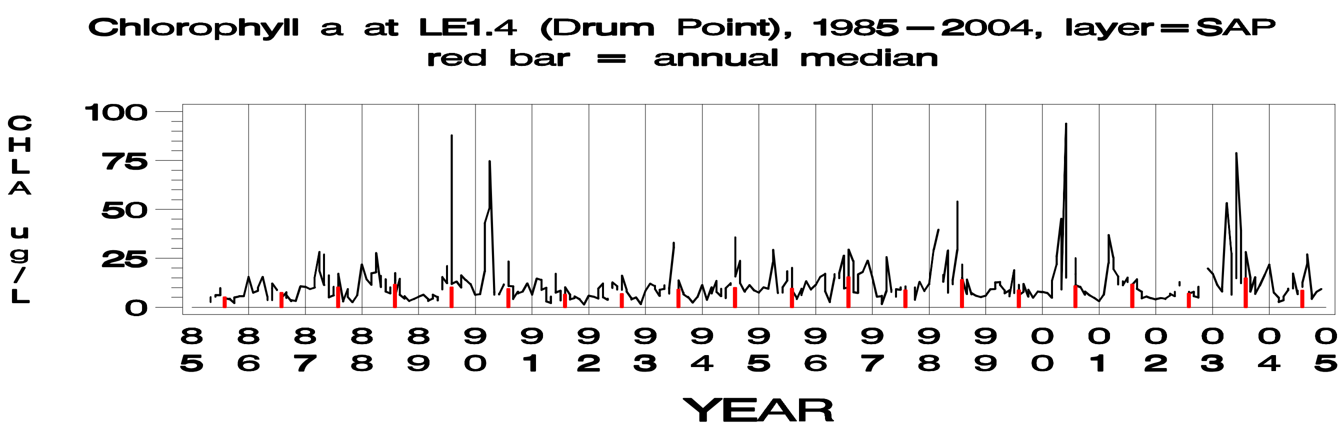


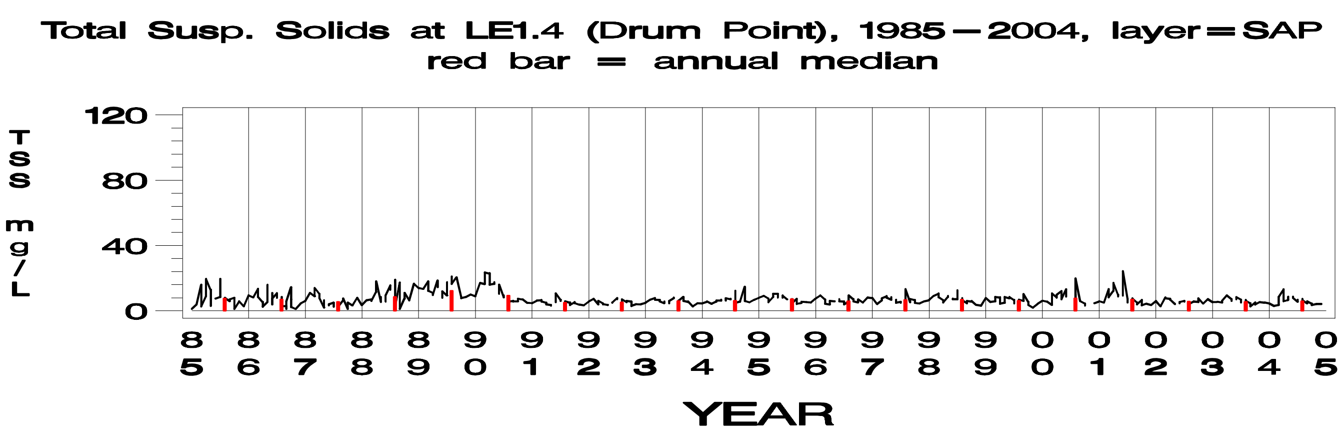
Water Temperature at LE1.3 (Above Pt. Patience), 1985 — 2004, layer=SAP
red bar = annual median



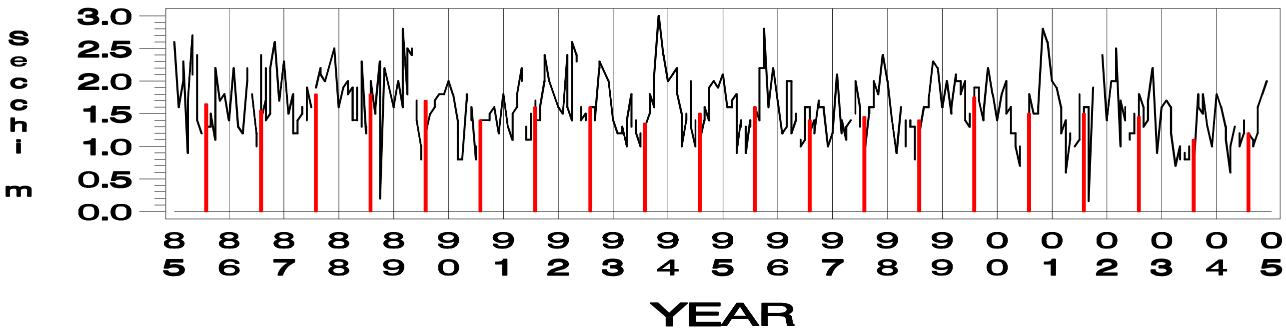

Total Nitrogen at LE1.4 (Drum Point), 1985—2004, layer=SAP
red bar = annual median
TN mg/L
0
2
4
6
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR


Total Phosphorus at LE1.4 (Drum Point), 1985—2004, layer=SAP
red bar = annual median
TP mg/L
0.0
0.1
0.2
0.3
0.4
0.5
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR

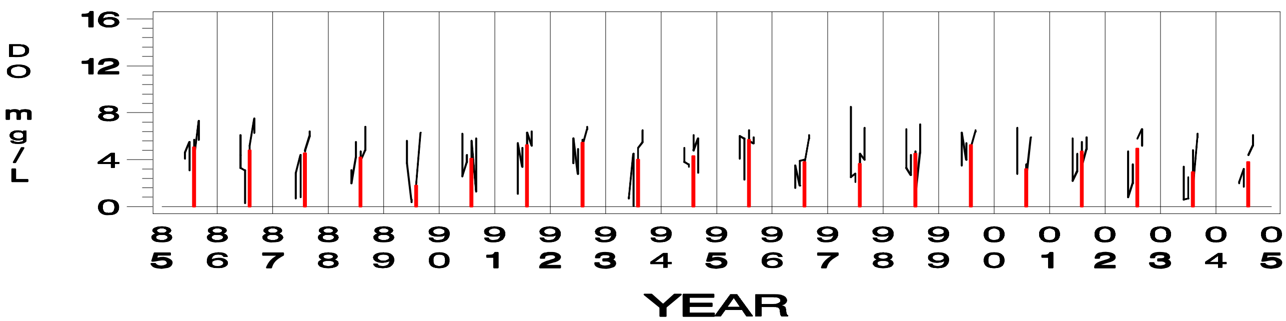

Chlorophyll a at LE1.4 (Drum Point), 1985—2004, layer=SAP
red bar = annual median
CHLA ug/L
0
25
50
75
100
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR


Total Susp. Solids at LE1.4 (Drum Point), 1985—2004, layer=SAP
red bar = annual median
TSS mg/L
0
40
80
120
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
YEAR

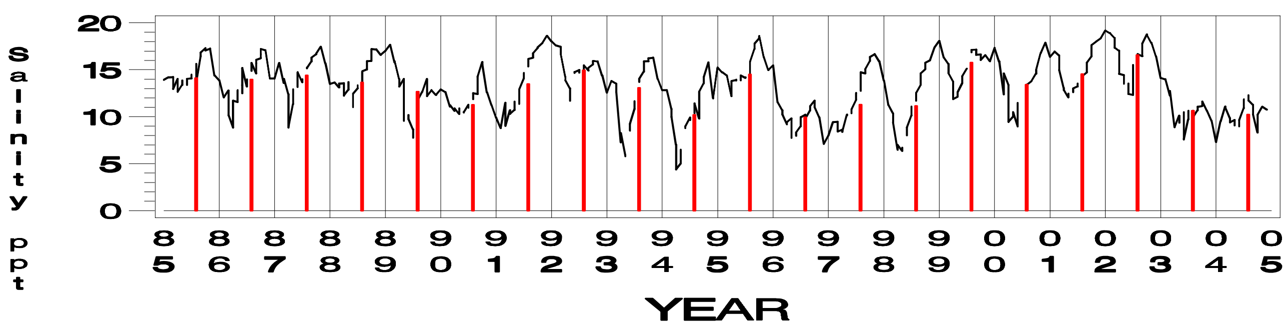
Secchi Depth at LE1.4 (Drum Point), 1985—2004, layer=S
red bar = annual median



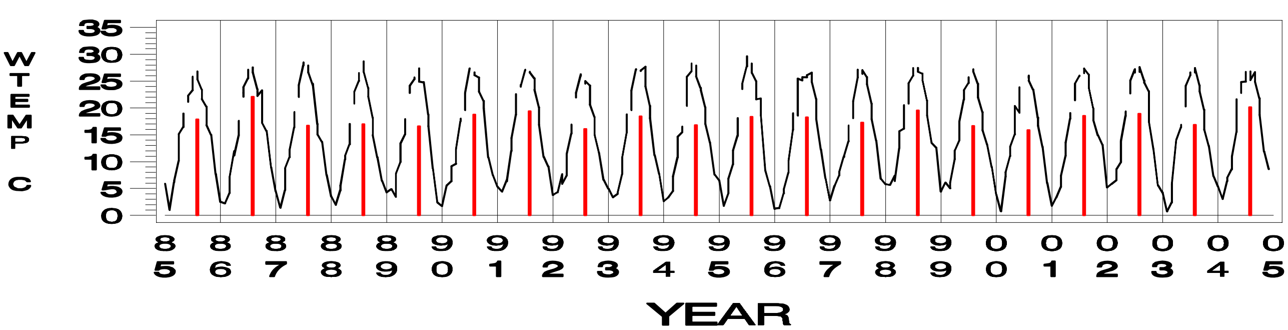
Dissolved Oxygen at LE1.4 (Drum Point), 1985—2004, layer=BDO
red bar = annual median



Salinity at LE1.4 (Drum Point), 1985—2004, layer=SAP
red bar = annual median



Water Temperature at LE1.4 (Drum Point), 1985—2004, layer=SAP
red bar = annual median



Appendix C – Nutrient Limitation Graphs for the Patuxent River Basin

US Rt. 50 (TF1.0) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) at all times. Total nitrogen concentration is relatively fair and improving (decreasing). Total phosphorus concentration is relatively poor but improving (decreasing). The ratio of total nitrogen to total phosphorus is increasing. Further reductions in nitrogen concentrations will be needed, especially in summer and fall, before nitrogen limitation can occur at this station. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.

Western Branch (TF1.2) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) at all times. Total nitrogen and dissolved inorganic nitrogen concentrations are relatively good and both are improving (decreasing); total phosphorus and dissolved inorganic phosphorus concentration is relatively good and dissolved inorganic phosphorus is improving (decreasing). Further reductions in nitrogen concentrations will be needed, especially in summer and fall, before nitrogen limitation can occur at this station. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.

MD Rt. 4 (TF1.3) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) at all times. Total and dissolved inorganic nitrogen concentrations are relatively poor but both are improving (decreasing). Total and dissolved inorganic phosphorus concentrations are relatively fair and both are improving (decreasing). The total nitrogen to total phosphorus ratio is decreasing. Further reductions in nitrogen concentrations will be needed, especially in summer and fall, before nitrogen limitation can occur at this station. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.

Jackson Landing (TF1.4) – Phytoplankton growth at this station is nutrient saturated (light limited or no limitation) more than 90% of the time and nitrogen limited less than 10% of the time. Summer growth is nitrogen limited about 20% of the time, and fall growth is nitrogen limited more than 10% of the time. Total and dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively fair and all improving (decreasing). Total phosphorus concentration is relatively poor but improving (decreasing). The ratio dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is low in the summer, indicating that phosphorus is in excess relative to nitrogen and nitrogen limitation is possible. Further reductions in nitrogen, particularly in the summer and fall, may increase the duration of nitrogen limitation. Significant reductions in phosphorus will be needed to allow phosphorus limitation to occur in this portion of the Patuxent, but any reductions in phosphorus are important to reduce the amount of phosphorus being exported to areas downstream.

Nottingham (TF1.5) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) 75% of the time and nitrogen limited 25% of the time. Growth in the summer is nitrogen limited more than 50% of the time. Growth in the fall is nitrogen limited approximately 40% of the time. Total nitrogen concentration is relatively fair and dissolved inorganic nitrogen concentration is relatively good; both are improving (decreasing). Total phosphorus concentration is relatively poor and dissolved inorganic phosphorus concentration is relatively fair; both are improving (decreasing). The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is low in the summer, indicating that phosphorus is in excess relative to nitrogen and nitrogen limitation should occur. Further reductions in nitrogen, particularly in the summer and fall, would increase the occurrences of nitrogen limitation. Much larger phosphorus reductions would be needed in winter and spring for phosphorus limitation to occur.

Lower Marlboro (TF1.6) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) 75% of the time and nitrogen limited 25% of the time. Growth in the summer is nitrogen limited 50% of the time. Growth in the fall is nitrogen limited almost 45% of the time. Total nitrogen concentration is relatively good, dissolved inorganic nitrogen concentration is relatively fair, and total and dissolved inorganic phosphorus concentrations are relatively poor, but all are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is low in the summer, indicating that phosphorus is in excess relative to nitrogen and nitrogen limitation should occur. Further reductions in nitrogen, particularly in the summer and fall, would increase the occurrences of nitrogen limitation. Much larger phosphorus reductions would be needed in winter and spring for phosphorus limitation to occur.

Above Benedict (TF1.7) – On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) 65% of the time and nitrogen limited 35% of the time. Growth in spring is occasionally nitrogen limited (approximately 5% of the time). Growth in the summer is nitrogen limited 60% of the time. Growth in the fall is nitrogen limited almost 55% of the time. Total nitrogen concentration is relatively good, dissolved inorganic nitrogen concentration is relatively fair, and total and dissolved inorganic phosphorus concentrations are relatively poor, but all are improving (decreasing). The ratio of total nitrogen to total phosphorus is decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is low in summer and fall, indicating that phosphorus is in excess relative to nitrogen and nitrogen limitation should occur. Further reductions in nitrogen, particularly in the spring and fall, would increase the occurrences of nitrogen limitation. Much larger phosphorus reductions would be needed in winter and spring for phosphorus limitation to occur.

Below Benedict (RET1.1) – On an annual basis, phytoplankton growth is nitrogen limited 70% of the time and rarely phosphorus limited (less than 5% of the time). Winter growth is nitrogen limited almost 40% of the time. Spring growth is nitrogen limited almost 60% of the time and phosphorus limited less than 5% of the time. Summer growth is nitrogen limited 95% of the time, and fall growth is nitrogen limited more than 65% of the time. Total nitrogen concentration is relatively fair, dissolved inorganic nitrogen concentration is relatively good, and dissolved inorganic phosphorus concentrations are relatively poor; all are improving (decreasing); total phosphorus concentration is relatively poor. The ratio of total nitrogen to total phosphorus is decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is low in spring and very low in summer and fall, indicating that phosphorus is in excess relative to nitrogen and consistent with the strong nitrogen limitation at this station. Further reductions in nitrogen have the potential for limiting phytoplankton growth in all seasons.

Reductions in phosphorus, particularly in the winter and spring, will bring the system into better balance.

Jack Bay (LE1.1) – On an annual basis, phytoplankton growth is nitrogen limited more than 80% of the time and rarely phosphorus limited (less than 5% of the time). Winter growth is nitrogen limited 50% of the time. Spring growth is nitrogen limited almost 80% of the time and phosphorus limited almost 10% of the time. Summer and fall growth is nitrogen limited 95% and 90% of the time, respectively. Total and dissolved inorganic nitrogen concentrations are relatively good and total and dissolved inorganic phosphorus concentrations are relatively fair, and all are improving (decreasing). The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is low in spring and very low in the summer and fall, consistent with the strong nitrogen limitation at this station. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Reductions in phosphorus concentrations, particularly in the spring, would help bring the system into better balance and allow for phosphorus limitation of growth as well.
St. Leonard (LE1.2) – On an annual basis, phytoplankton growth is nitrogen limited more than 85% of the time and phosphorus limited almost 10% of the time. Winter growth is nitrogen limited approximately 55% of the time and phosphorus limited about 5% of the time. Spring growth is nitrogen limited almost 85% of the time and phosphorus limited 10% of the time. Summer growth is nitrogen limited more than 95% of the time and otherwise is phosphorus limited. Fall growth is nitrogen limited 90% of the time and is otherwise phosphorus limited. Total nitrogen and total phosphorus concentrations are relatively good and improving (decreasing); dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively fair and improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing; this is low all year, especially in the summer and fall, consistent with the strong nitrogen limitation at this station. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Continued reductions in phosphorus concentrations, particularly in the winter and spring, would help bring the system into better balance and allow for increased phosphorus limitation of growth as well.

Above Pt. Patience (LE1.3) – On an annual basis, phytoplankton growth is nitrogen limited almost 85% of the time and phosphorus limited almost 10% of the time. Winter growth is nitrogen almost 65% of the time and otherwise nutrient saturated (light limited or no limitation). Spring growth is nitrogen limited 75% of the time and phosphorus limited 20% of the time. Summer growth is always nitrogen limited. Fall growth is nitrogen limited almost 85% of the time and is otherwise phosphorus limited. Total nitrogen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus concentrations are all relatively good and improving (decreasing); total phosphorus concentration is relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is very low, especially in the summer and fall consistent with the strong nitrogen limitation at this station. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Continued reductions in phosphorus concentrations, particularly in the winter and spring, would help bring the system into better balance and allow for increased phosphorus limitation of growth as well.

Drum Point (LE1.4) – On an annual basis, phytoplankton growth is nitrogen limited almost 65% of the time and phosphorus limited more than 20% of the time. Winter growth is nitrogen limited 45% of the time and phosphorus limited more than 5% of the time. Spring growth is phosphorus limited approximately 45% of the time and nitrogen limited approximately 35% of the time. Summer and fall growth is nitrogen limited almost 95% and more than 70% of the time, respectively. Total nitrogen and dissolved inorganic nitrogen concentrations are relatively good and improving (decreasing). Total phosphorus concentration is relatively good; dissolved inorganic phosphorus concentration is relatively fair and improving (decreasing). The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus are both decreasing. The dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is low in the summer and fall. Continued reductions in nitrogen will help increase the occurrences of nitrogen limitation in the winter and spring, and further suppress algal growth throughout the year. Reductions in phosphorus would increase phosphorus limitation in the spring.

Appendix D – Glossary

algae bloom – high concentrations of phytoplankton (algae).

benthos – bottom-dwellers.

dinoflagellates – a type of flagellated single-celled phytoplankton; most are photosynthesizers but some are also heterotrophic.

epiphytic – growing on a plant. Epiphytic algae grow on the leaves and stems of bay grasses.

estuary – a semi-enclosed, tidal, coastal body where fresh water running off land mixes with salt water coming in from the ocean.

hypoxia – the condition of low dissolved oxygen (< 2 mg/L), which is detrimental to many living organisms.

nauplius – an early planktonic stage in the life of a crustacean.

nutrient – chemicals required for plant growth and reproduction; in this report the term nutrients generally refers to nitrogen and phosphorus.

plankton - organisms that are unable to swim strongly, and drift along with currents; many are microscopic

phytoplankton – plankton that are “plant-like” in that they are primarily or partially autotrophic (primary producers); many are tiny single-celled organisms; examples include diatoms and dinoflagellates.

tributary – a stream, creek or river that feeds into a larger body of water.

watershed – a basin that drains into a particular body of water.

zooplankton – plankton that tend to be “animal-like” in that they are primarily heterotrophic (e.g., they eat other organisms); examples include copepods and rotifers.

Appendix E – References

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